SEWAGE WORKS JOURNAL

JANUARY, 1939 No. 1

Special Articles

First Year's Operation at Wards Island—Donaldson

Centrifuge for Sludge Concentration—Kraus and Longley

Flash Drying of Sludge—Reybold—Smith

Chemical Treatment at Waukegan—Swope

Moisture of Digesting Sludge—Sperry

Oxygen Demand of Activated Sludge—Sawyer and Nichols

OFFICIAL PUBLICATION OF THE
FEDERATION OF SEWAGE WORKS ASSOCIATIONS

This

Anniversary Volume . . .

is published to commemorate ten years of service by the Federation of Sewage Works Associations, and is dedicated to the many operators of sewage works, research workers, engineers and public officials who have contributed to the development of the art of sewage treatment in the past.

The editor of MODERN SEWAGE DISPOSAL is Langdon Pearse, and the following is a list of the chapters and their respective authors:

C. A. EMERSON, JR.: The Federation and Its Relationship to Sewage Disposal.

C. G. HYDE: A Review of Progress in Sewage Treatment During the Past Fifty Years in the United States.

LANGDON PEARSE: Functional Outline of Processes of Sewage Treatment.

SAMUEL A. GREELEY: Sedimentation and Digestion in the United States.

KARL IMHOFF: Sedimentation and Digestion in Germany.

W. E. STANLEY: The Trickling Filter in Sewage Treatment.

F. W. MOHLMAN: Twenty-five Years of Activated Sludge.

W. DONALDSON: Chemical Treatment of Sewage.

LINN H. ENSLOW: Chlorine in Sewage Treatment Practice.

GEORGE B. GASCOIGNE: Mechanical Equipment in Modern Sewage Treatment.

MORRIS M. COHN: Utilization and Disposal of Sewage Sludge.

W. D. HATFIELD: The Works Laboratory.

C. A. HOLMQUIST and C. C. AGAR: Bettering Sewage Plant Operation.

MAX LEVINE: Bacteriological Aspects of Sewage Treatment.

EARLE B. PHELPS: Bio-chemistry in Sewage Treatment.

W. C. PURDY: Limnological Aspects of Sewage Disposal.

N. T. VEATCH, JR.: The Use of Sewage Effluents in Agriculture.

H. W. STREETER: Disposal of Sewage in Inland Waterways.

A. K. WARREN and A. M. RAWN: Disposal of Sewage into the Pacific Ocean.

A. D. WESTON: Disposal of Sewage into the Atlantic Ocean.

WILLEM RUDOLFS: Sewage Research.

HAROLD E. BABBITT: Research in Sewage Treatment at Educational Institutions in the United States.

C. E. KEEFER: Administration of Sewage Treatment Works.

GORDON M. FAIR: Mathematical Aspects of Sewage Research.

C.-E. A. WINSLOW: Pioneers of Sewage Disposal in New England.

ABEL WOLMAN: State and Other Governmental Functions in the Control and Abatement of Water Pollution in the United States.

H. T. CALVERT: Governmental and Local Functions in the Control of Sewage Disposal in Great Britain.

J. H. GARNER: Sewage Treatment in England.

E. J. HAMLIN and H. WILSON: The Sewage Disposal Problem in South Africa.

H. J. N. H. KESSENER: Sewage Treatment in the Netherlands.

A. HEILMANN: Sewage Treatment in Germany.

L. F. WARRICK: The Prevalence of the Industrial Waste Problem.

ROBERT SPURR WESTON: Treatment and Disposal of Industrial Wastes.

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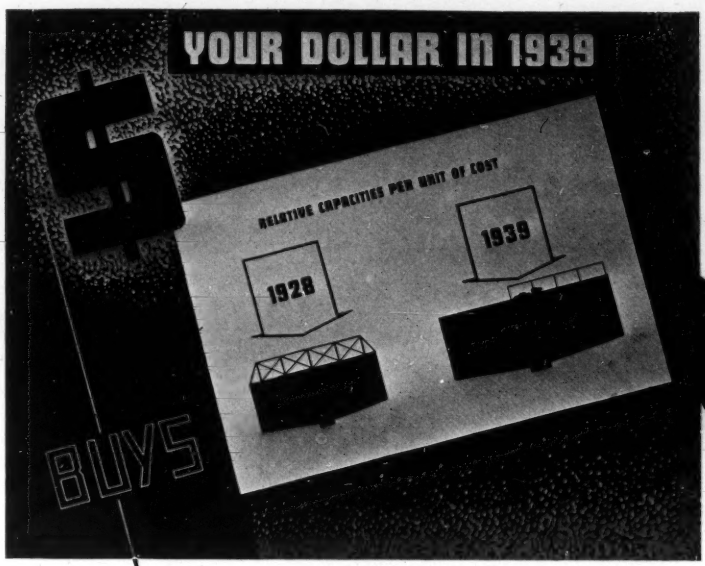

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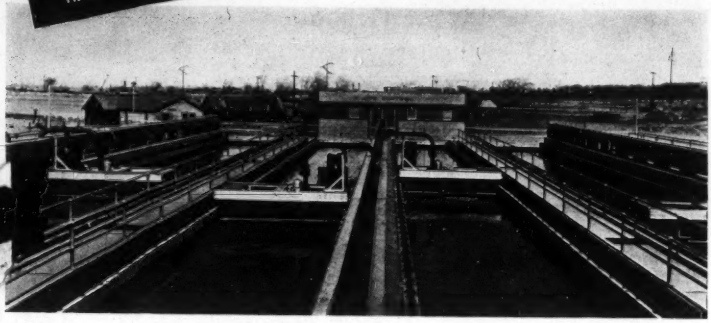

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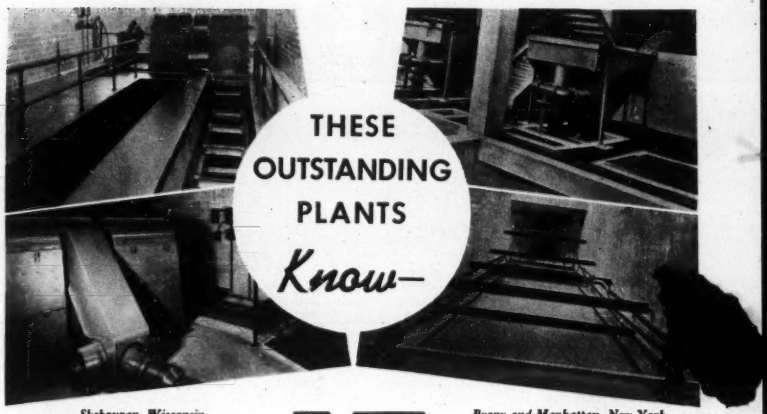

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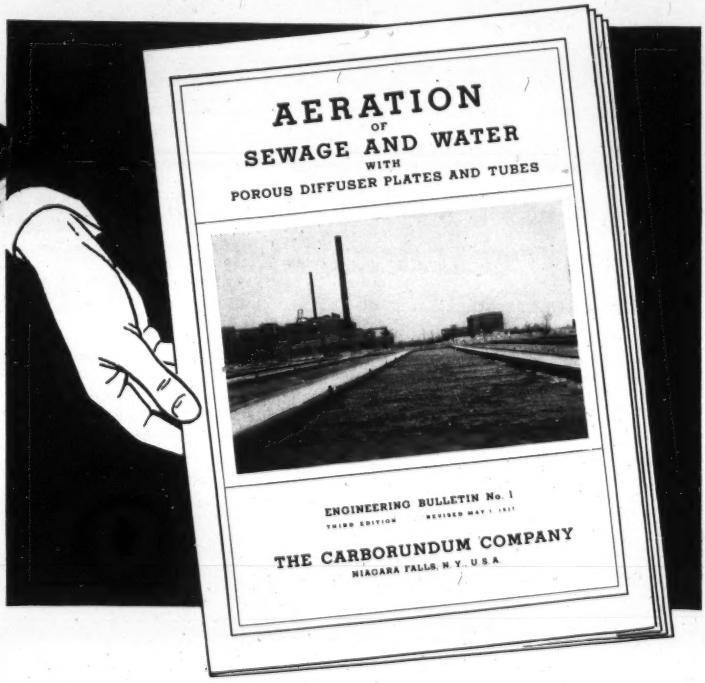

● The Carborundum Company invites every Sanitary Engineer, Plant Superintendent, Chemist and all others engaged in this important field, to send for a free copy of this authoritative and useful technical reference... a revision which has established its worth to hundreds during the past two years. This publication covers all applications of porous diffusers as used in sewage and water treatment plants. It provides the complete information and data essential to the study, design, installation and operation of porous diffusers in such plants. Write for your copy of this valuable bulletin.

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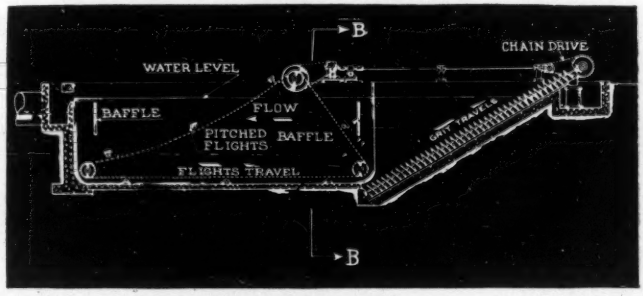

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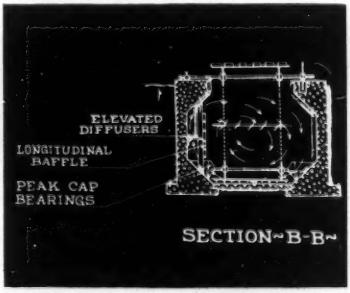

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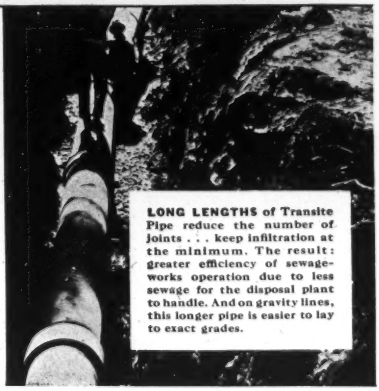

LONG LENGTHS of Transite Pipe reduce the number of joints . . . keep infiltration at the minimum. The result: greater efficiency of sewage-works operation due to less sewage for the disposal plant to handle. And on gravity lines, this longer pipe is easier to lay to exact grades.

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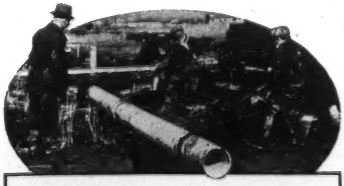

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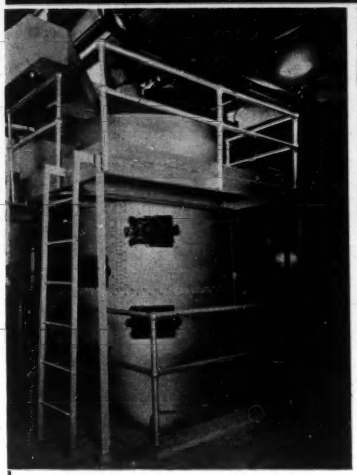
A reprint of this survey will be sent gratis on request.

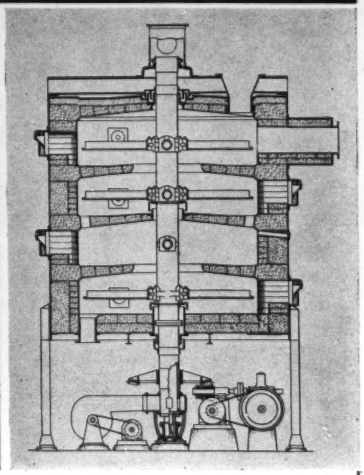
ANOTHER OUTSTANDING PUBLISHING SERVICE

The 1939 edition of Construction Costs will be published in the April 27 issue of *News-Record*. The 12th annual issue, this yearbook will present up-to-the-minute basic cost data at a time when the industry will be hitting its greatest stride since the boom days of 1929 and 1930. The essential facts for planning and financing projects and for preparing bids, evaluating, appraising and wage determination are covered. Subscribers to *News-Record* receive it gratis but buy hundreds of extra copies at $2.00 each. Avoid last-minute disappointment. Send in your order now and let us bill you when the edition appears.

Address inquiries for reprint of sewage disposal inventory and orders for Construction Costs issue to A. E. Paxton, 330 W. 42nd St., New York, N. Y.

CONVERTING 4 TONS OF SEWAGE SLUDGE INTO CLEAN ASH EVERY DAY





Burning—*properly controlled*—is the most sanitary, satisfactory and efficient method of disposing of sewage sludge. It reduces to sterile, harmless ash everything which might be dangerous to health or become a public nuisance.

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Dresser Catalog No. 36

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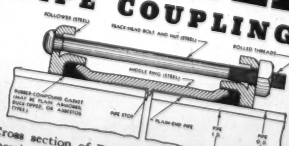

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Vol. 11
1939

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Cast iron pipe is made in diameters from 1¼ to 84 inches.

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Sewage Works Journal

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Vol. XI January, 1939 No. 1

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Sewage Research

APPLICATION OF THE PHOTRONREFLECTOMETER FOR THE MEASUREMENT OF TURBIDITY IN SEWAGE *

By Harry W. Gehm and Eugene H. Trubnick

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Attempts to measure turbidity by means of a photo-electric cell were at first unsuccessful, particularly when applied to liquids of heterogeneous nature such as sewage effluents. In most of the earlier work transmitted light was used and the degree of absorption by a sample of the liquid in question was measured. Holmes (1) obtained reasonably satisfactory results but required a rather cumbersome piece

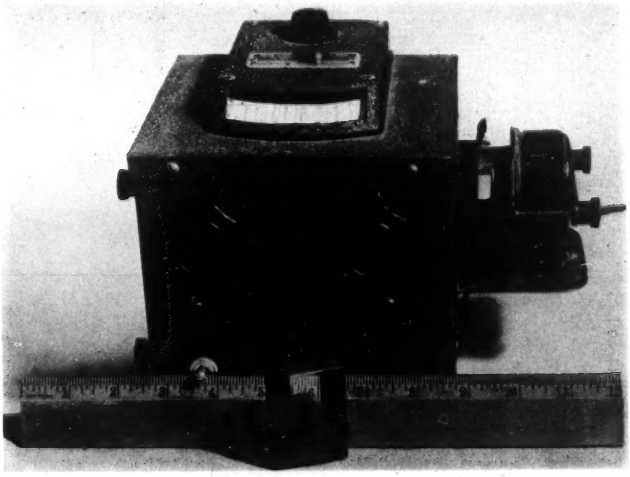

Fig. 1.—Photronreflectometer.

of apparatus. Watson (2) measured turbidity by this method employing light filters.

With the rise in interest in nephelometric measurement in biochemistry and bacteriology, methods were developed whereby the amount of light reflected by the particles in suspension was measured. Very

* Journal Series Paper, New Jersey Agricultural Experiment Station, New Brunswick, N. J., Department of Water and Sewage Research.

satisfactory results were reported on application of these devices to counting bacteria, determining sulfates and comparing serum reactions (3, 4, 5, 6). For a number of years we have been in search of a method which would eliminate personal error and cover a wide range of turbidities. Results obtained in other fields with the Libby Photronreflectometer led to experimentation and adoption of this apparatus.

The small instrument as shown in Fig. 1 consists of an automobile headlight bulb as a light source. Current is obtained from a transformer connected to a 110 volt A.C. outlet. The intensity of light is controlled by two rheostats, one being of low resistance and acting as a vernier. The light is projected in a pencil beam to the center of a Weston photo-cell, which is blocked out. When light is turned on no current is registered on the microammeter connected to the cell. How-

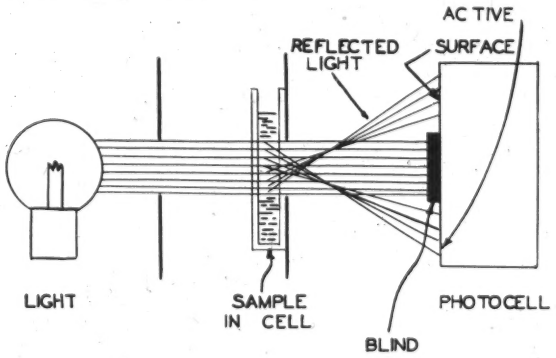

FIG. 2.—Diagram showing light reflection.

ever, when a turbid suspension is placed in the beam of light, reflected light from the suspended particles reaches the outer extremities of the cell, which are not blinded as shown in the diagram (Fig. 2). Thus the amount of light reflected by suspension is measured.

EXPERIMENTAL

For calibration a standard silica (turbidity) suspension of 100 p.p.m. was prepared according to Standard Methods of the A. P. H. A. (7). This suspension was diluted with distilled water to concentrations of 5, 10, 20, 30, 40, 50, 60, 70, 80, and 90 p.p.m. turbidity, while distilled water was used as a standard for 0 p.p.m. turbidity.

The glass cell of the photronreflectometer, with a capacity of 3.5 c.c., was filled with distilled water, placed in position and the zero setting adjusted. Then the 100 p.p.m. standard was placed in the cell and the light intensity regulated so that this suspension produced a microammeter deflection of 50 units on the scale.

Since a change in light intensity produced a variation in the zero setting, and a change in the zero setting affected the microammeter

readings throughout the scale, these two processes were repeated alternately until a combined setting was reached where distilled water produced a zero reading and the 100 p.p.m. suspension produced a reading of 50.

The diluted suspensions within this range were in turn placed in the cell, and the respective microammeter deflections read. The figures, when plotted, form a very smooth parabolic curve with a steep slope—almost a straight line (Fig. 3).

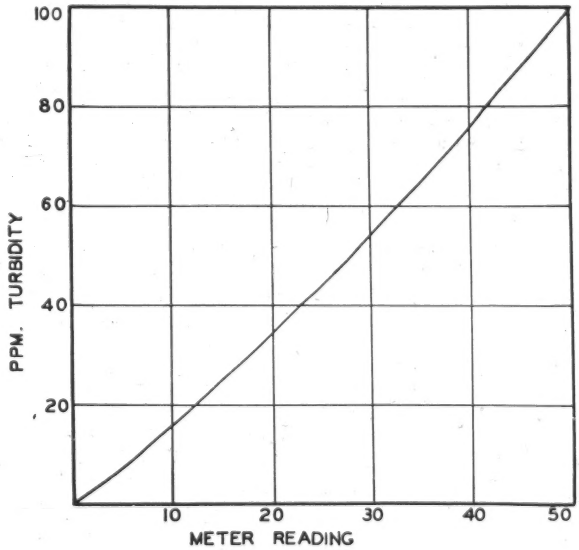

FIG. 3.—Calibration of photronreflectometer with silica standards for determination of turbidities in sewage.

In a similar manner the apparatus was calibrated with turbidities up to 400 p.p.m. With turbidities higher than 400 p.p.m., opacity affected the readings to an extent which definitely prohibited application of the instrument beyond this concentration.

Sewages were collected from three different plants and filtered through cotton to remove the larger particles. They were found to contain 90, 100 and 78 p.p.m. turbidity respectively.

Each of these sewages was then diluted to various concentrations, as had been the silica standard; and the microammeter deflection produced in the photronreflectometer by each concentration was determined. The results coincided with the figures obtained with silica in calibrating the instrument. In fact, a curve plotted from these results would coincide almost exactly with the calibration curve in Fig. 3.

To check further the accuracy of the instrument when applied to the measurement of sewage turbidities, sewage was treated with various amounts of $FeCl_3$ and the turbidities of the resulting supernatant liquids were determined with the photronreflectometer. When the results are plotted, a practically smooth curve, typical of chemical treatment-turbidity curves, is formed (Fig. 4).

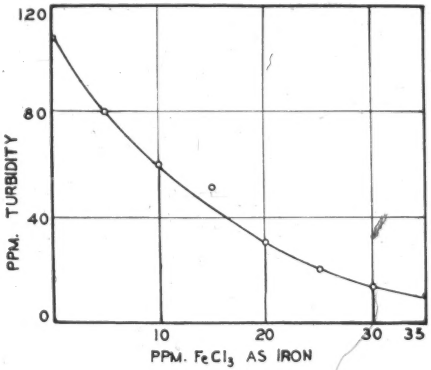

FIG. 4.—Turbidity of supernatant liquids after treatment with $FeCl_3$ as measured by instrument.

For comparisons with the "Standard Method" a number of samples of effluent were taken from the New Brunswick chemical sewage treatment plant. The photronreflectometer results (Table I) show an increase in turbidity between the hours of 9:00 a.m.–12:00 m., which is representative of conditions at any plant where the strength of the sewage increases rapidly during the morning. The results, however, do not show such great variations as the standard method. At the same time the results of both methods are reasonably close.

TABLE I.—*Turbidity of effluents from chemical treatment plant as measured by the photronreflectometer and standard methods (in p.p.m.)*

Time Sampled	Photronreflectometer	Standard Method
9:00 a.m.	13	17
9:30	31	24
10:00	31	32
10:30	34	37
11:00	36	40
11:30	37	33

DISCUSSION

The accuracy of the photronreflectometer when used for the determination of sewage turbidities is established (1) by the smoothness of

the curve formed from the results of the calibration with the silica standards; (2) by the coincidence of results obtained with sewages with those obtained with the silica suspensions; (3) by the typical results obtained with chemical treatment; and (4) by the results obtained with chemical effluent from an operating plant. Another indication is the fact that results of determinations made on six different portions of one silica standard coincided exactly.

The data obtained with diluted sewages compared very favorably with the results of the silica calibration. The following deviations from the silica curve were noted: About 45 per cent of the points fell on the curve, while the average deviation was 0.8 per cent.

9 points fell on the silica curve
22 points deviated 0.8 per cent
14 points deviated 3.3 per cent below the curve
5 points deviated 4.8 per cent above the curve

The largest single deviation was a microammeter reading of 36 instead of 34. This reading represents a turbidity of 67 p.p.m. instead of 63 p.p.m., an error insignificant in practical considerations.

Due to the extreme sensitivity of the instrument, a number of precautions are necessary in order to assure the degree of accuracy attained: (1) the apparatus must be placed on a level surface with a solid base, as any external vibrations influence the swing of the galvanometer needle; (2) the glass cell must be kept clean. Before a determination is made, the cell should be cleaned twice with distilled water and rinsed once with a portion of the sample to be tested. The cell should be filled with distilled water when not in use; (3) the outer metal case of the apparatus must be electrically grounded, in order to dissipate any static electricity which may have been generated. It was found that even the electricity generated by drying the exterior surfaces of the glass cell was sufficient to deflect the microammeter needle to a point as much as five units away from the true reading; (4) the zero and maximum settings should be checked with standards fairly often, preferably once a day.

Added advantages of the apparatus lie in the fact that readings can be made accurately in the low range of 0–20 p.p.m. and in the fact that a small sample, 3.5 c.c., is necessary for a determination.

Conclusions

The Libby photronreflectometer has been applied for use in the nephelometric determination of turbidities in sewage and has been found to have the following distinct advantage over the "standard" method.

1. Greater accuracy,
2. Application to determination of low and high turbidities,
3. Use of small sample,
4. Elimination of the personal factor.

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CONCENTRATING ACTIVATED SLUDGE WITH A CONTINUOUS FEED CENTRIFUGE*

By L. S. Kraus and J. R. Longley

Chemist and Engineer, Peoria Sanitary District

The disposal of activated sludge by digestion in separate digesters is made difficult by the fact that activated sludge does not always have the same degree of compactability. It has been our experience that the compactability varies to such an extent that sludge drawn from mechanically cleaned settling tanks may vary in solids content from as much as 3 per cent to less than 1 per cent. Low concentration causes

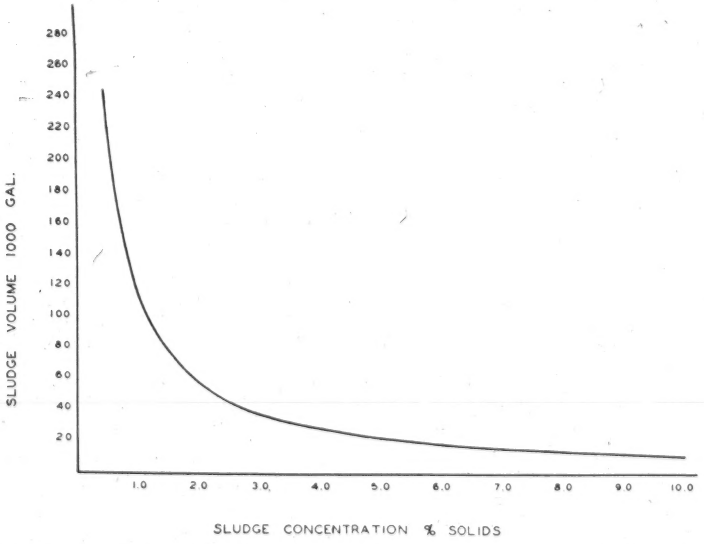

Fig. 1.—Curve indicating the volume of sludge containing 10,000 lbs. of dry solids for varying sludge concentrations.

the overloading of sludge handling facilities, particularly in reducing the period of storage in sludge storage tanks and in increasing drying time on sludge drying beds.

Figure 1 indicates the effect of compactability, or per cent solids in the sludge, on the volume of sludge necessary to be handled. In our case a 1 per cent solids waste activated sludge is typical. If it were possible to concentrate this waste activated sludge to 5 per cent solids

* Presented at the Eleventh Annual Convention of the Central States Sewage Works Association, Neenah-Menasha, Wis., Oct. 14, 1938.

a reduction of 80 per cent in the volume would obtained. This 80 per cent reduction would resolve itself into a 50 per cent reduction in the total volume of sludges handled throughout the plant over our present method of concentrating the sludges in the primary settling tanks, and the effect would be to double our digestion and storage periods.

Our problem is that of insufficient storage tank capacity. This study was undertaken to compare the feasibility and economy of the installation and operation of a continuous feed centrifuge with the construction and operating cost of additional storage tanks. The test was conducted over a six-month period, during which time the manufacturer had one of its engineers supervising the operation and maintenance of the equipment. After a period of preliminary studies the machine was placed in service and operated as continuously as possible.

The Centrifuge

The centrifuge consists of an 18-inch diameter bowl driven by a 10 H.P. motor at about 6,000 R.P.M. The machine is equipped with starting controls for taking the motor up to speed without undue overload, and brakes for bringing the bowl to rest after the motor is deenergized. A crane, vise, and bowl wrench are provided to facilitate the handling, dismantling and assembling of the bowl.

The bowl is provided with sludge discharge valves which permit practically continuous removal of concentrated sludge, and with discs which provide as much detention time as possible in order to improve clarification. The waste activated sludge, fed into the machine at as constant a rate as is possible, enters the regulating tube which conveys it to the bottom of the bowl. The concentrated sludge is thrown against the periphery of the bowl, from which it flows to the valve openings and is discharged into the sludge compartment housing. The effluent moves up through the discs and is discharged over the lip of the bowl into the effluent housing, which makes up the cover of the centrifuge.

When the sludge builds up on the periphery of the bowl to a sufficient depth to cover the end opening in the valve block, the supply of water which had been flowing through the valve shell orifice and out of the valve seat orifice is cut off. This causes the valve shell to fill with air and establishes a sufficient difference in density between the empty valve shell and the sludge in which it is immersed to cause the valve to be lifted away from the valve seat. This in turn causes the sludge to be discharged through the orifice in the valve seat. This discharge continues until the heavy sludge is removed from the valve block opening and water is again allowed to fill the valve shell. The water filled valve shell then closes against the valve seat, shutting off the flow of concentrated sludge, and allowing the concentrated sludge to build up until the valve block opening is closed and the cycle is ready for repetition.

The maximum opening in the valve shell orifices is 0.045 inch and the maximum opening in the valve seat orifices is $\frac{3}{16}$ of an inch. Due to the small orifice diameters employed in the centrifuge valves, screening

of the feed to the centrifuge is necessary in order to prevent clogging of these openings. When one of these orifices becomes clogged, concentrated sludge builds up in the bowl around the inoperative valve, causing the bowl to become unbalanced, thus necessitating a shut-down of the equipment and a complete cleaning of the bowl and valve orifices. With our waste activated sludge it was found that screening with a simple pressure type screen was inadequate and a Robbins Vibrex screen equipped with a 30-mesh Monel metal cloth was installed to effect the removal of large sludge particles.

Operation

After a period of experimenting and making adjustments the centrifuge was operated as continuously as possible, one of the plant operators being assigned to its operation on each eight-hour shift. Daily composites were made for analysis of the sludges and effluents from samples collected every half hour. Rates of flow and power consumption were determined hourly.

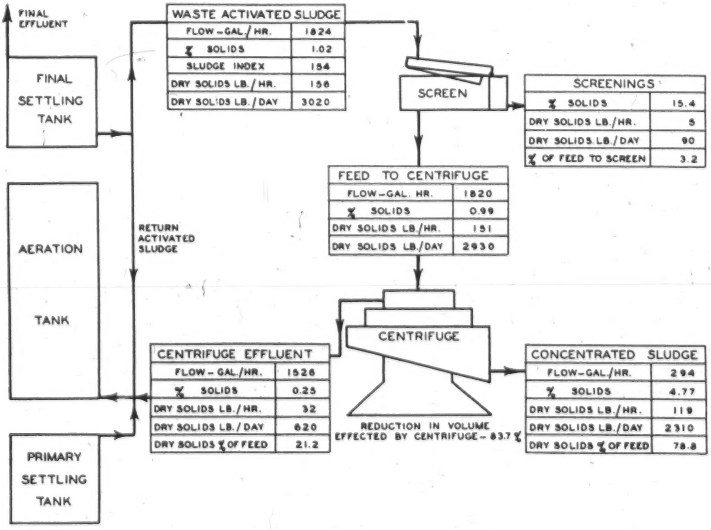

Fig. 2.—Flow diagram of centrifuge operation.

Figure 2 indicates in flow diagram the method of operation, together with some of the average operating data. One of the four batteries of primary, aeration and final tanks was operated in parallel with the remainder of the plant as a separate activated sludge unit and one-fourth of the total sewage flow was treated therein. All of the waste activated

sludge resulting from this operation was wasted to the vibrating screen and thence to the centrifuge. The effluent from the centrifuge was returned to the influent to the aeration tanks and the concentrated sludges wasted with the waste activated sludge from the remainder of the plant to the influent of the primary settling tanks. With a complete centrifuge installation the concentrated sludges would be wasted directly to the digestion tanks, but this was not done in this test due to the

TABLE I.—*Data on the concentration of activated sludge with a continuous feed centrifuge*

Period of Test Data—10/17/37 to 3/12/38	147 days
Number of Days of Test Data	120 days

Screen data

Feed to Screen		Screenings	
Rate of Feed gal./hr.	1824	% Solids	15.4
% Solids	1.02	% Volatile (Dry Basis)	90.5
% Volatile (Dry Basis)	80.5	Dry Solids lb./hr.	4.6
Sludge Index	154	Dry Solids lb./day	90
Dry Solids lb./hr.	156	Dry Solids % of Feed to Screen	3.2
Dry Solids lb./day	3020		

Centrifuge data

Feed to Centrifuge

Rate of Flow gal./hr.	1820
% Solids	0.99
% Volatile (Dry Basis)	80.2
Dry Solids lb./hr.	151
Dry Solids lb./day	2930

Concentrated Sludge		Centrifuge Effluent	
Rate of Flow gal./hr.	294	Rate of Flow gal./hr.	1525
% Solids	4.77	% Solids	0.253
% Volatile (Dry Basis)	79	% Volatile (Dry Basis)	81.9
Dry Solids lb./hr.	119	Sludge Index	232
Dry Solids lb./day	2310	Dry Solids lb./hr.	32
Dry Solids % of Feed to Screen	76.3	Dry Solids lb./day	620
		Dry Solids % of Feed to Screen	20.5

inability of obtaining a sufficient loading on a digester to make the data obtained worthy of interpretation.

Table I is an average of all of the data obtained between October 17, 1937, and March 12, 1938. The test period was 147 days; the test data used, however, covered but 120 days of operation. The results deleted from this test represent, in the main, periods of shut-down. Much of this time was lost awaiting the arrival of repair parts, many of which would be on hand if a permanent installation were made.

The rate of feed to the centrifuge was established empirically by determining the maximum rate which would result in a reasonable degree

of clarification and provide a concentration of 4 to 5 per cent solids in the concentrated sludge. It was found that with 1 per cent solids in the feed to the centrifuge a rate of about 1,800 gal. per hr. could be used. This resulted in an effluent that contained about 0.25 per cent solids and a concentrated sludge containing about 4.8 per cent solids.

The vibrating screen (Fig. 3), operated by a 3 H.P. motor, removed 3.2 per cent of dry solids in the feed to the screen. During the major portion of this test the screenings were quite dry, containing but 84.6 per cent moisture. This material could be readily mixed with the concentrated sludge from the centrifuge and pumped to the digestion tanks.

Of the total dry solids in the feed to the screen 76.3 per cent was discharged as concentrated sludge from the centrifuge and 20.5 per cent was returned to the influent of the aeration tanks as centrifuge effluent.

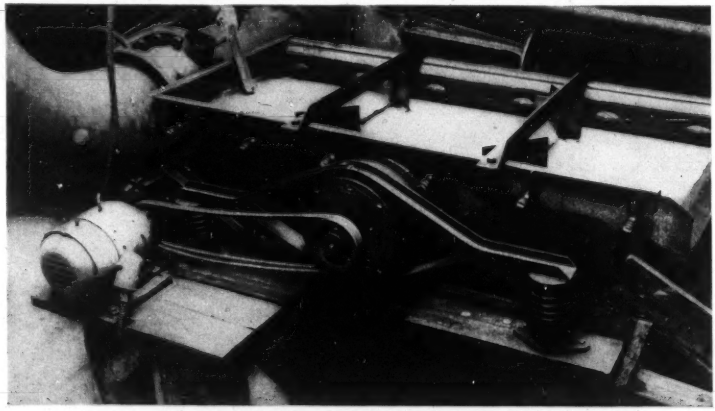

FIG. 3.—Robbins Vibrex Screen used to screen sludge before centrifuging.

The action of the centrifuge is such as to concentrate the lower density solids in the centrifuge effluent. It was noted early in the test that the sludge index of the centrifuge effluent was considerably higher than the sludge index of the waste activated sludge. Much concern was expressed regarding the building up of the lower density solids in the activated sludge, thus resulting in a marked decrease in the ability of the centrifuge to concentrate the sludge. During the test this effect was not of sufficient moment to upset the centrifuge operation. The return of the centrifuge effluent to the aeration tanks did, however, increase the sludge index in that tank above the sludge index of the rest of the plant. This increase was not sufficient to interfere with plant operation.

Table II is a summary of the centrifuge operating data. A centrifuge employing this type of bowl requires that the material thrown against the side of the bowl be of a viscous nature so that it will flow to

TABLE II.—*Summary of centrifuge operation*

Hours of Operation per Day	19.4
Number of Cleanings of Bowl per Day	4
KW. Input to Motor	9.3
Volume of Feed to Screen gal./hr.	1824
Total Volume of Concentrated Sludges gal./hr.	298
% Reduction in Volume	83.7
% of Solids in Feed Wasted as Concentrated Sludges	79.5
Dry Solids in Concentrated Sludges lbs./day	2400
Number of Centrifuges Required for Handling All of the Waste Activated Sludge	5

the valve orifices. Activated sludge has the necessary viscous property causing it to flow to the valve orifices; however some of the denser gritty

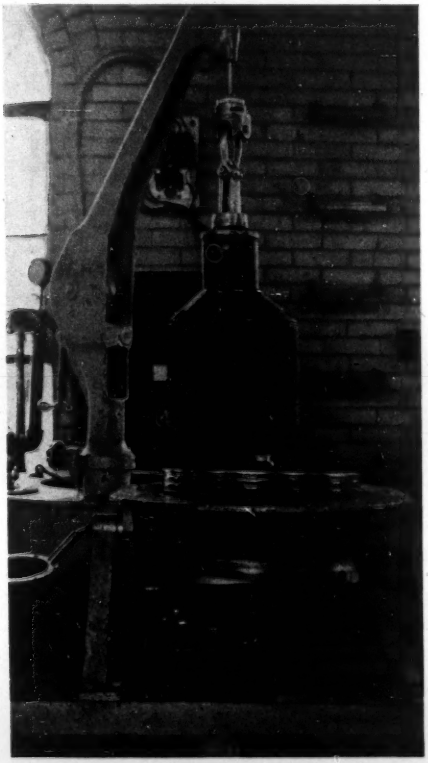

FIG. 4.—Valve bowl vise with discs held by crane ready for assembly. Ports in bowl take valve seats. Bowl top to left of bowl vise.

particles of the activated sludge tend to accumulate on the side of the bowl. This accumulation continues until its depth is such that it builds up into the discs (Fig. 4) and upsets clarification. It is then necessary to shut down the centrifuge in order to clean the bowl. Centrifuge shut-downs are also brought about by the clogging of the valve shell and valve seat orifices. During the test the bowl was cleaned an average of four times per day. These shut-downs and shut-downs for repairs reduced the average hours of centrifuge operation for the period of the test to 19.4 hours per day.

Because of the very high velocities of discharge of concentrated sludge in the centrifuge a fine mist is formed which if breathed for a prolonged period induces symptoms of a very bad chest cold. In this test it was necessary to vent the concentrated sludge discharge tank to the atmosphere outside the building and to provide as much ventilation as possible in order to provide satisfactory working conditions around the centrifuge. Undoubtedly this problem must be considered in the design of a permanent installation.

The motor load averaged 9.3 KW., one day's operation requiring about 181 KWH.

TABLE III.—*Estimate of cost of centrifuge installation*

3 Screens Complete with Tanks and Controls at $800 each	$ 2,400
5 Centrifuges, Complete with Electrical Controls at $7,000	35,000
Erection of Equipment	1,200
Piping, Tanks and Flow Control Devices	2,000
Electric Wiring	500
Total Installation Cost	$41,100

The centrifuge effected a reduction in volume of feed of 83.7 per cent, with 79.5 per cent of solids in the feed to the screen being recovered in the concentrated sludges. The actual reduction in volume effected by concentrating sludge from 1.02 to 4.77 per cent solids is 78.5 per cent. The dry solids capable of being discharged by the centrifuge as concentrated sludge, together with the screenings from the vibrating screen, was 2,400 lbs. per day. In order to concentrate all of the waste activated sludge at the Peoria plant a minimum of five centrifuges would be required. The five centrifuges could be served by three vibrating screens.

Table III is an estimate of the cost of the centrifuge installation at the Peoria plant. It assumes the installation of five centrifuges and three screens, together with the necessary piping and control devices in an existing available building. It assumes that no additional pumping equipment will be necessary and that the power line serving this building will be adequate to carry the necessary load. The estimate of cost is not based on a detailed layout but the $41,100 first cost estimate is considered to be conservative.

Table IV is an estimate of the yearly cost of operation. Fixed charges are based on a 15-year equipment life and a 3.5 per cent interest

TABLE IV.—*Estimate of yearly costs for operation of centrifuge installation*

Fixed Charges—15 Year Life and 3½% Interest, $41,100 × 8.68% =	$ 3,570
Operators 3½ at $1,650	5,775
Maintenance Materials and Special Services	
5 Centrifuges at $200	1,000
3 Screens at $100	300
Power—Continuous Load of 45 KW., 390,000 KWH. per Year at 0.5¢/KWH.	1,950
Miscellaneous Supplies and Services	105
Total Annual Cost	$12,700

Dry Solids Concentrated per Year

$$\frac{5 \times 2{,}400 \times 365}{2{,}000} = 2{,}190 \text{ Tons per Year}$$

Cost of Concentrating Waste Activated Sludge

$$\frac{12{,}700}{2{,}190} = \$5.79 \text{ per Ton of Dry Solids}$$

rate. The five centrifuges and three screens will require the continuous presence of an operator. The cost of operators is based on our present rate for such labor. Maintenance of the centrifuges at $200 per machine per year is based on an offer of a five-year maintenance contract made by the equipment manufacturer. It is our feeling that over the 15-year maintenance period the $200 maintenance cost will be exceeded. The maintenance of the screens is largely made up of wire cloth replacement.

Power costs are based on the assumption that the 45 KW. increment of load at the treatment works will be supplied by an existing gas-engine driven generator. Total annual cost of operation is estimated to be $12,700, during which period 2,190 tons of dry solids will have been discharged as concentrated sludge. This adds up to a total of $5.79 per ton of dry solids as the cost of increasing the solids concentration of the waste activated sludge from about 1 per cent to 4.77 per cent.

SUMMARY

The results of the test may be summed up as follows:

The centrifuge is capable of increasing the concentration of waste activated sludge from 1 per cent solids to about 5 per cent solids.

The effluent from the centrifuge contains about 2,500 p.p.m. suspended solids.

The return of the centrifuge effluent to the aeration tanks did not seriously affect the operation of the activated sludge plant, nor did it interfere seriously with the centrifuge operation.

The maximum rate of feed to the centrifuge consistent with reasonable solids concentration in the concentrated sludge and a fair degree of clarification is about 1,800 gallons per hour. This assumes a waste activated sludge concentration of 1 per cent solids.

The maximum rate of feed to the centrifuge is not inversely proportional to the concentration of waste activated sludge. A sludge containing 0.5 per cent solids cannot be fed to the centrifuge at 3,600 gallons per hour but more nearly in the order of 2,500 gallons per hour. The clarification at this rate will not be good and the power required will increase considerably.

Sludges containing more than 1 per cent solids must be fed to the machine at rates lower than 1,800 gallons per hour.

The average power required by the centrifuge is of the order of 9.3 KW.

The volume reduction effected by the centrifuge on the waste activated sludge is between 75 and 80 per cent.

The total cost of concentrating our waste activated sludge from 1 to 5 per cent solids by means of the centrifuge is estimated at $5.79 per ton of dry solids.

The centrifuge cannot handle primary tank sludge or digested primary tank and activated sludge because of the gritty materials present in these sludges.

Discussion on Mr. Kraus' Paper on the Use of High Speed Centrifuge for Concentration of Activated Sludge at Peoria, Ill.

By G. J. Strezynski

Engineer of Design, The De Laval Separator Company

The use of a high speed centrifuge for concentration of activated sludge was very well described by Mr. Kraus from the standpoint of its use at Peoria, Illinois. Similar tests were carried out in other locations for periods of many months. These tests indicated certain differences in performance and cost which I would like to point out.

Peoria sewage is somewhat different from the normal sewage found in most other cities, which is no doubt due to distilleries and other industries located in the district. The raw sewage carries 300 p.p.m. of suspended solids and the excess activated sludge contains only 0.5 to 1.0 per cent solids on a dry basis. Both facts contribute towards the necessity of using more machines per daily flow than would be required by other plants. Peoria has a raw sewage flow of 14 m.g.d., however if this sewage was diluted to 200 p.p.m. it would amount to 21 m.g.d. On the other hand the excess activated sludge is at least 50 per cent more in amount than found in other plants where the activated sludge shows about 1½ per cent suspended solids on a dry basis. From this it may be readily seen that while Mr. Kraus needs one machine for each 3 m.g. flow, under normal conditions one machine will handle about 6 m.g.d. Daily operation of the machine for 8 hours each day took care of all excess activated sludge in a town where the raw sewage flow was 5 m.g.d. and where the activated sludge contained 2.0 per cent solids in suspension.

The estimated operating cost of the installation is subject to variable conditions and accounting. Tests carried over a period of several

months indicated that when the machine was used for concentration of activated sludge and the concentrated activated sludge was fed directly to the digesters, the rate of gas production increased very definitely and the digested sludge showed a larger proportion of mineral matter to organic matter.

The increased gas production may be due to the fine aeration of the concentrated activated sludge in the machine itself or it may be due to the fact that as the sludge is subjected to this high centrifugal force and the tremendously violent spraying, almost all organic life is broken up and all the larger particles of sludge are shredded to very fine fragments. Numerous microscopic inspections of the centrifuged sludge almost always showed a complete absence of active life. Only in one case did the centrifuged sludge show some life under the microscope. To be specific, this destruction of organic life does not extend to the bacteria growth.

In plants where the gas is used for generation of power or heat the increased gas production would more than make up for the power necessary for the operation of the machines. The increased rate of gas production would reduce the necessary digestion period so that the capacity of the digesters would be increased not only on account of higher solids content in the digester liquor but also by the reduced time of digestion.

I fully agree with Mr. Kraus that at the present time it would be advisable to have an operator at all times in the building where the machines are located. For that reason the location of the machines should be carefully considered, to avoid if possible the necessity of a special operator. In most plants there is an operator in continual service in the pump building. This operator usually has a very limited amount of actual work and could be readily assigned to the operation of the machines. As the wages of the operator are the major part of the operating expense as estimated by Mr. Kraus, the whole cost of operation becomes a question of accounting, that is, the proper apportioning of his time between the machines and the other plant equipment.

The remaining large item in the operating cost is based upon the manufacturer's offer of keeping the machines in operating condition for a flat yearly payment per machine. This offer was made because this application of centrifugals is new and as an incentive to make one of the first installations. It is not a general policy of the manufacturer or of other suppliers of comparable equipment and it is obvious that as the manufacturer does not have control over the maintenance of the equipment it was necessary to allow an ample margin in establishing the yearly maintenance figure. It is to be expected that the actual cost of repairs will be considerably lower if the equipment is properly maintained.

In conclusion it may be said that the operating cost of the machines per ton of solids even when based on the highest estimate is only a fraction of the cost involved by chemical treatment.

HIGH AND LOW TEMPERATURE DIGESTION *

VI. SUPERNATANT LIQUOR TREATMENT WITH CHEMICALS

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The problem of disposal of supernatant liquor is one of the difficulties encountered in separate sludge digestion. Dewatering of the material on sand beds can be practiced where small quantities are present, sufficient sand bed area is available and the odor problem is of no consequence. Dewatering on covered sand beds is more certain, but clogging of sand causes difficulties in operation. Returning the supernatant liquor to the settling tank causes some deterioration in the effluent, and if followed by oxidation devices the additional solids produce an additional load. This may be serious when the activated sludge process is used or when the capacity of the oxidation device is limited. The problem of disposal of supernatant liquor from sludge digested under thermophilic conditions presumably may be of even greater importance on account of the rather rapid passage of sludge through the tanks. In the case of successive digestion under thermophilic and mesophilic conditions the liquor is more completely clarified, but still contains considerable fine and dissolved material. It is well nigh impossible to remove from the liquid the material in solution, but removal of the suspended material and a part of the dissolved substances would alleviate difficulties in final disposal.

Thermophilic Sludge Liquor

The results reported are indicative of what can be done by chemical treatment with this troublesome liquor as well as showing the limitations of the method employed. A number of tests were made to facilitate treatment; some of the results are presented to indicate the possibilities. The results given deal with liquor from some sludges to which trade wastes were added, producing the most odorous and densest liquors; they are presented mostly in the form of tabulated notes. In the case of odorous liquors, high in dissolved and finely divided suspended solids, the question of odor control is perhaps as important as the removal of the solids. Since chlorine is used extensively for odor control and has been shown to reduce the B.O.D. of sewage liquors, tests with chlorine added prior to the addition of coagulants were considered of interest. The supernatant liquors used had disagreeable, penetrating odors, which however did not carry far and were easily dissipated into the air. As an example of the effect of chlorine and coagulants on the supernatant liquors, condensed results obtained from a series of tests are given in Table I. The chlorine demand of the supernatant liquor amounted to 930 p.p.m. With 10 per cent of the chlorine demand

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TABLE I.—*Effect of chlorine and coagulants on supernatant liquors*

P.p.m. Chlorine Added	Odor After Chlorination	Coagulant		Floc	Settling	Color Liquid	Odor After Adding Coagulant	Remarks
		Type	P.p.m.					
0– 37	Present	Alum	170	Slight	None	Grey black	Intensified	No clarification
46–280	Present—9.3 p.p.m.	Alum	85	Slight	None	Grey—84 p.p.m., thereafter brownish	Penetrating, intensified	No clarification
375	Absent	$FeCl_3$	100	Fine	½ hr.	Brown	Returned	Insufficient clarification
470	Absent	Ferrous sulfate	1000	Some, fine	Slow	Greyish	Strong	Insufficient clarification
560	Absent	$FeCl_3$	500	Coarse, light	Floc floats	Yellow	Returned	Good clarification
650	Absent	Alum and H_2SO_4	90 1500	Slight	None	Yellow	Strong	Discoloration only
750	Absent	NaOH	600	Slight	None	Brown	Strong	Dispersion
840	Absent	$Ca(OH)_2$	600	Heavy, fluffy	Some	Yellowish	Considerable	Clear liquid but much sludge
930	Absent	Alum	90	None	Little	Yellowish	Some	Clear liquid but poor settling

satisfied, odors could be eliminated, but even with complete satisfaction of the chlorine demand there was no coagulation. The black liquor was changed to a greyish mass and considerable quantities of coagulant were needed to cause flocculation and proper settling. Only when chlorination was complete did the odors fail to return after the addition of coagulants. With about 60 per cent of the chlorine demand satisfied by use of 500 p.p.m. $FeCl_3$, good clarification was obtained, but the odor returned after the addition of the coagulants. Since it appeared impossible to remove the odor and at the same time to clarify the liquid with reasonable quantities of chlorine, alone or in conjunc-

TABLE II.—*Effect of ferric chloride on clarification of suspended liquor*

$FeCl_3$		Color	Odor	Floc	Settling	pH
P.p.m.	Lb./1000 Gal.					
0	0	Grey black	Penetrating	None	None	6.8
100	0.83	Grey black	Fairly strong	Little, fine	Slight	6.4
200	1.66	Grey	Fairly strong	Little, fine	Considerable	6.0
300	2.50	Grey	Fairly strong	Considerable	Considerable	5.4
400	3.30	Greyish yellow	Some	Coarse	Good, compact	5.0
500	4.15	Greyish yellow	Slight	Coarse	Compact and clearly defined	4.6

tion with coagulants, some condensed results obtained from experiments with different common coagulants are presented. All mixtures were stirred at 15 r.p.m. for 15 minutes and allowed to stand for 30 minutes. Moderate quantities of ferric chloride (Table II) produced a good floc and with larger quantities a fairly good compact sludge was produced, but not much clear liquid separated upon settling. Further treatment by filtration would be necessary.

The total alkalinity of the sludge liquors is appreciable, and since it could be expected that at lower pH values better coagulation would take place, part of the total alkalinity was neutralized with sulfuric acid

before ferric chloride was added. Some condensed results are shown in Table III. The pH of the untreated liquor was 7.2 and the total alkalinity amounted to 1,600 p.p.m. After partial neutralization of alkalinity, ferric chloride was added, mixed for 15 minutes and the solids were allowed to settle for 15 minutes. The results show that floc formation and separation of the water from the floc particles could not be accomplished by partial neutralization of the alkalinity. With increasing neutralization the quantity of ferric chloride required decreased, so that with the destruction of half the alkalinity, 300 p.p.m. $FeCl_3$ were required and with the destruction of three-fourths of the alkalinity only 200 p.p.m. $FeCl_3$ were necessary to produce a clear, yellowish supernatant liquid and a coarse, rapidly settling floc. The quantities of ferric chloride were slightly too high, resulting in partial

TABLE III.—*Effect of destruction of alkalinity before ferric chloride addition or clarification of supernatant liquor*

Alkalinity Destroyed P.p.m.	$FeCl_3$ P.p.m.	pH Begin	pH End	Color Supernatant	Odor	Floc	Settling	Sludge by Volume Per Cent	Remarks, Sludge
400	100	6.2	5.6	Black	Strong	Fine, fluffy	Slow	None	No separation
	200	6.2	5.2	Grey black	Strong	Fine, fluffy	Slow	90	Thin, watery
	300	6.2	4.6	Yellow grey	Strong	Medium	Medium	17	All at bottom
	400	6.2	4.2	Clear	Some	Coarse *	Rapid	15	5% on top
800	0	5.2	5.2	Black	Strong, putrescible, pungent, onion	None	No	None	Thin
	100	5.2	5.0	Grey black	Considerable	Fine, fluffy	Slow	90	Thin
	200	5.2	4.6	Grey	Considerable	Fine, fluffy	Slow	90	Thin
	300	5.2	3.8	Clear yellowish	Considerable	Coarse *	Rapid	16	Half on top
	400	5.2	2.7	Clear	Some	Coarse * Dense	Rapid	8	All on top
1200	100	4.8	4.5	Yellowish grey	Considerable	Fine	Little	None	No separation
	200	4.8	2.8	Clear, yellow	Some	Coarse *	Rapid	16	Half on top
	300	4.8	2.5	Clear	Little	Coarse *	Rapid	15	8% on top
	400	4.8	2.2	Clear	Little	Coarse *	Rapid	15	10% on top
1000	0	1.2(?)	1.2(?)	Black	Little	Fine	None	0	Dispersion

* Floc yellowish, like milk curdle.

flotation of the sludge. Destruction of three-fourths of the total alkalinity and addition of 160 p.p.m. $FeCl_3$ produced clear liquid and a rapidly settling floc, without flotation. It will be noted that with pH values below 4.0 floc formation and settling were rapid. Results show that when the alkalinity is neutralized to produce a pH value of 3.4 (by a combination of acid and coagulant) or to about pH 4.0 (with acid alone) and sufficient iron salt is added to cause coagulation, a good floc, rapid settling, separation of a clear liquid, and subsequent compacting of sludge can be obtained. Treatment of supernatant liquor by chemicals is therefore not impossible and not as expensive as might be expected.

Similar experiments were made, with part of the alkalinity destroyed by commercial strong sulfuric acid, and with alum as coagulant. Some of the condensed results are shown in Table IV. The alum employed was ordinary commercial alum (17 per cent aluminum trioxide). Total alkalinity of the supernatant liquor was 1600 p.p.m. Preliminary experiments showed that the rate of stirring was of some

TABLE IV.—*Effect of partial destruction of alkalinity and alum addition on clarification of suspended liquor*

Alkalinity Destroyed P.p.m.	Alum P.p.m.	pH Begin	pH End	Color Supernatant	Odor	Floc	Settling	Sludge, by Volume Per Cent
400	100	6.2	6.2	Grey	Strong	Very fine	Very slow	95
	200	6.2	6.2	Grey	Strong	Very fine	Very slow	95
	300	6.2	6.2	Yellow	Strong	Very fine	Very slow	90
	400	6.2	6.2	Yellow	Strong	Very fine	Very slow	90
800	100	5.2	5.2	Greyish	Strong	Fine	Very slow	95
	200	5.2	5.2	Greyish	Strong	Fine	Very slow	90
	300	5.2	5.2	Yellow	Strong	Fine	Very slow	90
	400	5.2	5.2	Yellow	Strong	Fine	Very slow	90
1200	100	4.8	4.8	Yellowish grey	Strong	Medium	Slow	90
	200	4.8	4.8	Yellowish grey	Strong	Medium	Slow	85
	300	4.8	4.8	Yellowish grey	Strong	Medium	Slow	80
	400	4.8	4.8	Yellow	Strong	Medium	Slow	80
1300	200	4.0	3.9	Yellow	Considerable	Coarse	Medium rapid	50
	300	4.0	3.9	Yellow	Considerable	Coarse	Medium rapid	24
1450	100	3.4	3.3	Yellow	Some	Very coarse	Very rapid	16
	200	3.4	3.2	Yellow	Some	Very coarse	Very rapid	12

importance. Even with stirring at a rate of 15 r.p.m. some of the fragile floc was broken up. The results reported were obtained by inverting the mass twice. Further mixing was unnecessary or detrimental. Although a fine or medium floc was formed, which settled slowly, the separation of the liquid was rather poor with additions of alum up to neutralization of 75 per cent of the alkalinity. When the pH values of liquid separated were between 4.0 to 3.2 floc formation increased rapidly and good settling was obtained with production of comparatively small volumes of sludge. Best results were secured and smaller amounts of alum were required when the pH values were reduced to about 3.2.

TABLE V.—*Effect of addition of calcium hydroxide*

$Ca(OH)_2$ P.p.m.	pH Begin	pH End	Color Supernatant	Odor	Floc	Settling	Sludge, by Volume Per Cent
100	7.2	7.4	Grey	Strong	Extremely fine	Very slow	95
200	7.2	7.6	Grey	Strong	Extremely fine	Very slow	90
300	7.2	7.9	Grey	Strong	Extremely fine	Very slow	90
400	7.2	8.2	Grey	Strong	Fine	Very slow	90
500	7.2	8.4	Grey	Strong	Fine	Very slow	90
600	7.2	8.7	Brownish	Very strong	Medium	Slow	85
700	7.2	9.2	Brown	Very strong	Medium	Slow	80
800	7.2	9.6	Brown	Penetrating	Coarse, fluffy	Slow	50
1400	7.2	10.4	Yellow	Penetrating	Coarse fluffy,	Fair	40

The results with ferric chloride and alum indicate that supernatant liquor can be treated properly, without undue nuisance, provided the pH is reduced to about 3.2 to 3.6. The quantities of coagulant are not excessive because the volumes to be treated are comparatively small.

Since floc formation and settling took place under proper acidic conditions, it seemed probable that similar effects would be obtained under alkaline conditions. Portions of the same supernatant liquor used previously were treated with a slurry of calcium hydroxide, mixed by inverting twice, and allowed to stand for 15 minutes. Some condensed results are shown in Table V. It is evident that the quantities of lime required would be greater than to raise the pH value to 9.6. Raising the pH to 10.4 produced a floc which settled fairly well, but was still rather voluminous.

Discussion

Although thermophilic digestion produces a supernatant high in dissolved and finely divided suspended solids, chemical methods of treatment may be employed to produce a fairly compact sludge and a rather clear supernatant liquor. Neutralization of part of the alkalinity and subsequent treatment with a coagulant such as ferric chloride or alum is practical. The quantities of acid and coagulant are not excessive. When thermophilic digested sludge is treated with acid, considerable quantities of carbon dioxide are released. If the mass is not kept in motion the addition of acid results in frothing and foam formation which may be troublesome. The attempt to kill odors by use of chlorine was of considerable interest. Unless the chlorine demand of the sludge was satisfied, the addition of chemicals such as alum, ferric chloride, sulfuric acid, sodium hydroxide or lime caused a return of the odor. It appears that chlorine was capable of taking care of the substances which caused the odors (mostly sulfur compounds, but also nitrogenous degradation products) progressively with increasing quantities of chlorine. Ferric chloride acted similarly so far as certain sulfur compounds are concerned, but when some chlorine was added, followed by ferric chloride, pungent ammoniacal odors returned. The addition of alkalies increased the intensity of the odors. Apparently the addition of acidic material was sufficient to release odorous substances. Although the odors were penetrating they did not carry far and were easily dissipated in air. The odors were more intense when organic nitrogenous wastes were added to the digesting mixtures and these odors returned principally after treatment with the coagulants or coagulating aids.

Conclusions

1. Addition of increasing quantities of chlorine progressively reduced odor, but was not very effective in coagulation, up to satisfaction of the chlorine demand.

2. Addition of coagulants to partially chlorinated liquor caused a return of odors.

3. Moderate quantities of ferric chloride produced a good floc, but a rather large volume of sludge.

4. Partial neutralization of alkalinity did not materially aid in reduction of coagulant; lowering the pH values to 3.4 to 4.0 and subsequent addition of ferric chloride produced a good floc, rapid settling and compact sludge, and clear liquor could be obtained. Addition of alum was somewhat less effective.

5. Additions of lime to raise the pH value to 10.4 produced a fair settling, but rather voluminous floc.

Mesophilic Sludge Liquor

In applying chemicals for the clarification of mesophilic supernatant liquor the same technique was used as in treatment of the thermophilic liquor except that the 15-minute stirring period was abandoned in favor of a single flash mix. The action of the chemicals is very rapid and they diffuse rapidly in supernatant liquor. Trials proved excessive agitation to be of doubtful advantage. In some cases the solids separating out were whipped into a froth and refused to settle. Settling was measured at intervals in liter cylinders.

Results

(A) *Ferric chloride.*—A sample of supernatant liquor was obtained from a properly operating digester at Freehold, N. J. This sample had the following analysis.

pH	6.5
Turbidity (Settled)	508 p.p.m.
Total Solids	1356 p.p.m.
Susp. Solids (Settled)	364 p.p.m.
Odor—Ripe Sludge	
Color—Yellow	
Total Alkalinity	1988 p.p.m.

The first form of treatment applied was with $FeCl_3$ alone in dosages increasing from 50 to 500 p.p.m. It will be seen on examination of Table VI that best results from the standpoint of clarification were obtained with a dosage of 500 p.p.m. $FeCl_3$. At this dosage, however, sludge volume was excessive and the sludge layer separated, part settling and part rising to the top. At 200 p.p.m. a reasonable degree of clarification was obtained with all sludge floating. The sludge volume was about one-third that obtained with 500 p.p.m. $FeCl_3$, but the higher dosage removed the color, which the lower one failed to do. In both cases the odor did not become objectionable. Both sludges showed a strong compacting tendency. Taking the advantages and disadvantages into consideration, it appears that most satisfactory treatment was obtained with the lower amount of coagulant.

Sulfuric acid was added in order to neutralize a portion of the alkalinity prior to addition of increasing dosages of $FeCl_3$. This test was made to determine if some of the ferric salt was expended in merely

TABLE VI.—*Freehold supernatant liquor treatment with ferric chloride*

$FeCl_3$ as Iron P.p.m.	pH		Sludge Vol. 15 Minutes		Sludge Vol. 1 Hour			Supernatant After Treatment				Type of Floc
	Initial	Final	Top %	Bottom %	Top %	Bottom %	Total %	Color	Odor	Turb. P.p.m.	Alk. P.p.m.	
50	6.5	6.5	7.0	1	5.5	1	6.5	Yellow	Tarry	312	1898	Aver.
100	6.5	6.4	11.5	0	8.0	0	8.0	Yellow	Tarry	240	1790	Large
200	6.5	6.1	13.5	0	11	0	11	Yellow	Tarry	120	1480	Large
300	6.5	5.9	14.0	0	11	2	13	Yellow	Tarry	84	1252	Large
400	6.5	5.7	13.0	5	10	4.5	14.5	Faint yellow	Tarry	36	880	Very large
500	6.5	5.4	7.0	40	12	15	27.0	Clear	Strong, tarry	15	602	Large clots

supplying acidity or hydrogen-ions. If this were true, the cheaper sulfuric acid could be substituted for part of the ferric chloride. Sludge volume might also be decreased, because less hydrated iron oxide and organic iron compounds would be formed. Sufficient acid was added to lower the pH to 6.0, practically the same as that at which best results were obtained with $FeCl_3$ alone.

Results of this treatment, shown in Table VII, indicate that clarification increased only slightly, flotation of the sludge occurred and sludge

TABLE VII.—*Freehold supernatant liquor treatment with ferric chloride and low sulfuric acid dosage*

$FeCl_3$ as Fe P.p.m.	H_2SO_4 P.p.m.	Final pH	Sludge Vol. 15 Minutes		Sludge Vol. 1 Hour			Supernatant After Treatment *	
			Top %	Bottom %	Top %	Bottom %	Total %	Turbidity P.p.m.	Color
0	450	6.1							Yellow
25	450	6.0	2.0	3.0	4.0	3.5	7.5	400	Yellow
50	450	5.9	5.0	1.5	6.0	1.5	7.5	248	Yellow
100	450	5.9	8.5	5	6.5	0.5	7.0	200	Yellow
150	450	5.8	8.5	0	6.5	1.5	8.0	112	Yellow
200	450	5.8	11.0	0	8.5	0	8.5	84	Slight yellow
300	450	5.5	13.5	0	10.0	1.0	11.0	40	Slight yellow

* Odor = tarry; floc = fine, normal—all cases.

volume was not materially reduced. These tests indicated that little if any advantage was gained by the supplemental use of acid in quantity sufficient to lower the alkalinity to the point of optimum coagulation with ferric chloride alone.

There is an optimum point of coagulation of sewage with acid around pH 3.0. It was thought that perhaps supernatant liquor might respond in like manner, hence a dosage of 1,350 p.p.m. of sulfuric acid was added to the liquor both alone and with increasing dosages of ferric chloride.

The ferric chloride was added first, as this was found to be the better order of dosage in sewage. Low pH values allow the iron salt to remain in solution.

Inspection of Table VIII, containing the data obtained from these trials, shows that in this method of treatment the acid exerted some

TABLE VIII.—*Freehold supernatant liquor treatment with ferric chloride and sulfuric acid to optimum pH for sewage coagulation*

$FeCl_3$ as Iron P.p.m.	H_2SO_4 P.p.m.	Final pH	Sludge Vol. 15 Minutes		Sludge Volume 1 Hour			Supernatant After Treatment *		Type of Floc Formed
			Top %	Bottom %	Top %	Bottom %	Total %	Color	Turb. P.p.m.	
			Scum		Scum					
0	1350	3.6		1	1.0	1.0	1.0	Yellow	456	Heavy floc rises with gas
25	1350	3.4		2	1.5	1.5	3.0	Milky brown	228	Heavy floc rises with gas
50	1350	2.9	7	0	3.0	1.5	4.5	Milky brown	170	Heavy floc rises with gas
75	1350	2.7	8	0	3.0	1.0	4.0	Milky brown		Heavy floc rises with gas
100	1350	2.6	7	0	3.0	1.0	4.0	Milky brown	116	Heavy floc rises with gas
150	1350	2.4	8	0	5.0	2.0	7.0	Milky brown	86	Heavy floc rises with gas
200	1350	2.3	10	0	8.4	6.0	14.4	Milky brown	84	Good floc

* Odor = tarry with sour fresh solids.

effect. The advantages were that the same degree of clarification could be obtained with half the amount of $FeCl_3$ and the sludge volume was less than half that when $FeCl_3$ was employed alone. The disadvantages were the formation of considerable scum, the formation of a sour fresh-solids odor in the liquor and no great reduction in total cost of chemicals.

Caustic soda in sufficient amount to convert the bicarbonate to carbonate was next tried, in conjunction with $FeCl_3$. The pH was raised

TABLE IX.—*Freehold supernatant liquor treatment with ferric chloride and caustic soda*

$FeCl_3$ P.p.m.	NaOH P.p.m.	Final pH	Sludge Volume		Supernatant After Treatment *		Type of Floc Formed
			15 Min. %	1 Hour %	Color	Turb. P.p.m.	
0	850	8.9	11.5	8.5	Brown	356	Hairy
50	850	8.8	20.0	15.0	Brown	296	Large clots
100	850	8.7	25.5	19.0	Brown	204	Large clots
200	850	8.5	36.0	25.0	Brown	170	Large clots
300	850	8.2	53.0	35.5	Yellow	81	Large clots

* Odor: tarry, caustic.

to between 8.0 and 9.0 with caustic and then the coagulant was applied. With this method, flotation of sludge did not take place, as is shown in Table IX. Clarification, however, was good only when excessive dosages of $FeCl_3$ were used and in all trials the sludge volumes were excessively large. The color of the liquor became brown and a disagreeable caustic odor was given off.

Lime in addition to ferric chloride was next applied with more success than any of the other accessory chemicals (Table X). Twelve

TABLE X.—*Freehold supernatant liquor treatment with ferric chloride and lime suspension*

$FeCl_3$ as Fe P.p.m.	$Ca(OH)_2$ P.p.m.	Final pH	Sludge Volume		Supernatant Liquor After Treatment *	
			15 Minutes %	1 Hour %	Color	Turb. P.p.m.
0	1200	7.6	3.5	4.0	Yellow	424
25	1200	7.3	6.0	5.5	Yellow	312
50	1200	7.1	10.0	8.0	Yellow	224
75	1200	7.3	12.0	9.5	Yellow	204
100	1200	7.1	14.5	11.0	Yellow	184
150	1200	6.8	16.5	11.0	Yellow	112

* Odor = tarry; floc = good, compact.

hundred p.p.m. of lime reduced the ferric chloride dosage necessary for good clarification by 25 per cent, did not enlarge the sludge volume, enhanced compacting, deposited all the sludge on the bottom and did not give rise to disagreeable odors or other disadvantageous characteristics.

(B) *Alum.*—In the following experiments alum was substituted for ferric chloride as the coagulant for supernatant liquor treatment. Trials were made with alum alone and with caustic soda, sulfuric acid and lime. Results presented in Table XI show that large dosages of

TABLE XI.—*Treatment with alum alone (Freehold supernatant liquor)*

Alum as Al P.p.m.	Final pH	Sludge Volume		Supernatant After Treatment *		Type of Floc Formed
		15 Min.	1 Hour			
		Bottom %	Bottom %	Color	Turb. P.p.m.	
50	6.6	4.0	3.5	Yellow	456	Fine
100	6.6	6.5	5.0	Yellow	424	Normal
150	6.5	10.0	7.5	Yellow	408	Coarse
300	6.4	18.0	12.5	Yellow	356	Very large
500	6.2	22.5	15.0	Yellow	216	Very large

* Odor = ripe sludge.

alum gave very little clarification and that relatively large volumes of hydrate floc were formed. The sludge settled to the bottom.

When the alkalinity of the liquor was partially destroyed by the addition of 450 p.p.m. of sulfuric acid and increasing amounts of alum were added, clarification was obtained, as shown in Table XII. To obtain a satisfactory liquor 500 p.p.m. of alum as aluminum was required. The sludge volume was not excessive and the solids floated. The clear liquor appeared to contain a large amount of dissolved alum.

An application of 1350 p.p.m. of H_2SO_4, which lowered the pH to 2.9, did not aid clarification with even a very large alum dose. Treatment

with caustic soda to destroy the bicarbonates gave a fair degree of clarification but formed a very bulky sludge. Solids settled well and compacted rapidly but a large volume resulted. The odor was caustic and not agreeable. Substituting lime for sodium hydroxide gave some clarification, but even with very high lime applications (Table XII) the treated liquor was not satisfactory. Sludge volume was high and part of the sludge layer floated to the top.

(C) *Lime-Ferric Chloride Treatment.*—This form of treatment appeared to offer the best possibilities for supernatant liquor clarification.

TABLE XII.—*Freehold supernatant liquor treatment with Alum plus H_2SO_4, NaOH and $Ca(OH)_2$*

Alum as Al P.p.m.	Other Chemicals P.p.m.	Final pH	Sludge Vol. 15 Minutes		Sludge Volume 1 Hour			Supernatant After Treatment				Type of Floc Formed
			Top %	Bottom %	Top %	Bottom %	Total %	Color	Odor	Turb. P.p.m.	Alk. P.p.m.	
200	H_2SO_4 450	5.9	4.0	2.0	2.5	3.5	6.0	Yellow	Strong tarry	312	1300	Fine
300	H_2SO_4 450	5.8	5.0	2.0	3.0	4.0	7.0	Yellow	Strong tarry	296	1280	Normal
500	H_2SO_4 450	5.7	7.5	0	6.5	0	6.5	Grey	Strong tarry	90	1140	Normal
500	H_2SO_4 1350	2.9	Foam	1.0	Foam	2.0	2.0	Yellow	Fresh solids	368		Foamy
500	NaOH 850	8.5	0	45.0	0	18.5	18.5	Grey	Caustic tarry	160		Very large clots
500	$Ca(OH)_2$ 1200	6.6	15.0	4.0	6.5	7.0	13.5	Grey	Tarry	216		Very large clots

From the standpoint of clarification it had been noted in former experiments that lime added in suspension was far superior to addition in the dry state. Other work had also shown that lime water gave better results than a lime suspension. The limitation is the low solubility of lime, which necessitates the addition of a large volume of water.

The supernatant liquor was obtained from the Princeton, N. J., plant, contained 3174 p.p.m. of suspended solids, and had a pH of 6.9.

In the first experiment, lime solution and a lime suspension containing 20,000 p.p.m. were compared. The volumes were kept constant to determine the effect of dilution and to facilitate comparisons and final calculations. A tabulation of some results (Table XIII) shows that

TABLE XIII.—*Effect of lime in suspensions and in solutions (Princeton supernatant)*

Chemicals		Sludge Volume			Turb. Remaining P.p.m.	Final pH
Lime (Suspension) P.p.m.	Lime (Solution) P.p.m.	15 Min. %	½ Hour %	1 Hour %		
	0	24	21	19	496	6.7
	100	20	21	18	232	6.95
	200	35	28	23	140	7.20
	300	61	43	30	76	7.6
	400	100	73	50	84	7.6
100		22	20	18	440	6.8
200		22	20	17.5	424	6.9
300		23	20	17.5	356	7.0
400		22	21	18.5	272	7.1
500		27	23	20	120	7.2

Odor = ripe sludge; color yellow grey.

300 p.p.m. of $Ca(OH)_2$ added in solution gave a supernatant of 76 p.p.m. turbidity while the same amount added in suspension gave a treated liquor of 336 p.p.m. turbidity. Even 500 p.p.m. added in suspension gave much poorer clarification. However, sludge volumes were decidedly higher with the lime water addition. Both types of sludges produced a rapidly compacting sludge, the lime-water sludge being the more rapid, probably due to its originally higher volume.

The next trials were made using varying quantities of $Ca(OH)_2$ in solution and ferric chloride in varied dosages (Table XIV). As

TABLE XIV.—*Treatment with ferric chloride and lime water (Princeton supernatant liquor)*

$Ca(OH)_2$ Lime Water P.p.m.	$FeCl_3$ as Iron P.p.m.	Sludge Volume		Turbidity Remaining P.p.m.	Final pH	$Ca(OH)_2$ Lime Water P.p.m.	$FeCl_3$ as Iron P.p.m.	Sludge Volume				Total Volume in 1 Hour %	Turbidity Remaining P.p.m.	Final pH
								15 Min.		1 Hour				
		15 Min. %	1 Hour %					Top %	Bot. %	Top %	Bot. %			
0	0	17	13	468	6.9	0	200	38	3	22	0	22	116	6.2
93	0	16	11	370	6.9	93	200	35	28	27	1	28	88	6.3
185	0	26	17	256	7.1	185	200	0	60	10	34	44	74	6.4
278	0	27	19	190	7.2	278	200	0	40	0	27	27	70	6.5
370	0	33	23	176	7.4	370	200	0	39	0	24	24	63	6.7
555	0	46	23	86	7.7	555	200	0	57	0	25	25	47	7.1
0	50	35	22	334	6.7	0	300	13	31	18	17	35	78	6.1
93	50	23	17	196	6.8	93	300	45	10	19	4	23	61	6.3
185	50	22	16	190	6.9	185	300	0	55	0	39	39	52	6.5
278	50	21	15.5	184	7.0	278	300	25	37	25	5	30	50	6.5
370	50	32	21.5	120	7.2	370	300	0	63	0	40	40	45	6.6
555	50	50	27.5	62	7.6	555	300	0	60	0	35	35	43	6.8
0	100	36	27.5	212	6.5	0	500	5	53	5	37	42	64	5.8
93	100	31	24	181		93	500	8	37	7	23	30	55	5.9
185	100	31	24	154		185	500	15	33	9	23	32	46	6.2
287	100	29	23	103		278	500	8	44	5	35	40	35	6.2
370	100	31	24	78		370	500	6	57	4	39	43	30	6.3
555	100	50	30	37	7.5	550	500	8	80	8	36	44	30	6.6

the ferric chloride dosage necessary for coagulation increased the amount of lime dropped. The use of ferric chloride with lime did not increase markedly the sludge volume, but without lime the sludge became voluminous. When 200 p.p.m. or more of iron was applied the sludge layer showed a tendency to divide, part floating and part settling. The relationship between the dosage of lime water and that of ferric chloride needed for coagulation is shown in Fig. 1.

(D) *Miscellaneous Treatment Methods.*—Another type of treatment tried for supernatant liquor clarification was settling with Bentonite suspension. A suspension containing 29 mgm. of Bentonite was added in increasing quantities to three samples of supernatant liquor. The mixture was agitated thoroughly and allowed to settle for two hours. Turbidity was determined on the treated liquor and the sludge volume measured.

Good clarification could be obtained with this clay if added in sufficient quantities (Table XV). In all cases, between 725 and 1,450 p.p.m. were necessary. The sludge volumes were large, but not excessively so, with no tendency to float. As this material is inert, no tendency to change the character of the liquor to which it was added was exhibited.

It was thought that trials using a coagulant and a soluble divalent salt would be of interest. Calcium chloride was selected, because this salt had been found to be effective, when added in sufficient quantities, in aiding sewage coagulation. Alum and ferric chloride were used,

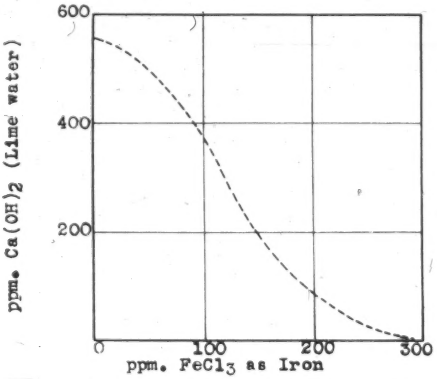

FIG. 1.—Amounts of chemicals necessary to give good clarification of supernatant liquor.

along with large doses of this salt. The results of this treatment on Freehold supernatant liquor are given in Table XVI. The removals of turbidity over that obtained by use of the same dosages of $FeCl_3$ and alum alone were slightly greater, but the sludge volume, particularly in the case of ferric chloride, was increased greatly by the addition of calcium chloride. The floc formed was a heavy clot with ferric chloride and a very large floc with the alum. Sludge separation also took place. In other than these phenomena, little change in the liquor could be attributed to the $CaCl_2$.

The use of an ammonia zeolite prior to application of $FeCl_3$ was tried. It was thought possible that some of the compounds responsible

TABLE XV.—*Treatment of supernatant liquor with Bentonite suspension*

Bentonite P.p.m.	Plainfield Supernatant Liquor Settled Turbidity 535 P.p.m.		New Brunswick Supernatant Liquor Settled Turbidity 395 P.p.m.		Freehold Supernatant Liquor Settled Turbidity 508 P.p.m.	
	Sludge Volume %	Turbidity Remaining P.p.m.	Sludge Volume %	Turbidity Remaining P.p.m.	Sludge Volume %	Turbidity Remaining P.p.m.
290	8.0	278	7.5	158	6.5	310
435	8.0	220	8.5	124	7.5	275
580	9.5	168	8.5	108	8.0	213
725	11.0	160	9.5	86	9.0	189
1450	15.5	128			11.5	96

TABLE XVI.—*Treatment with $FeCl_3$ and $CaCl_2$ and alum and $CaCl_2$ (Freehold supernatant liquor)*

Coagulant $FeCl_3$ as Fe P.p.m.	$CaCl_2$ P.p.m.	Final pH	Sludge Volume 15 Minutes		Sludge Volume One Hour			Supernatant After Treatment			Type of Floc
			Top %	Bottom %	Top %	Bottom %	Total %	Color	Odor	Turb. P.p.m.	
100	1000	6.5	17	3.0	15.5	2.5	18.0	Yellow	Ripe sludge	208	Large clots
200	1000	6.2	22	2.5	20.5	2.0	22.5	Yellow	Ripe sludge	69	Large clots
P.p.m. Alum as Al	P.p.m.										
300	1000	6.4	14	1.0	7.0	1.5	8.5	Yellow	Ripe sludge	336	Floc large
500	1000	6.1	16	2.0	8.5	1.0	9.5	Grey	Ripe sludge	248	Floc large

for the consumption of $FeCl_3$ might be removed by such treatment. Fifty grams of the zeolite was shaken with a liter of the liquor and the solid allowed to settle. Ferric chloride was then added in the usual manner. The results obtained showed that no improvement resulted from the zeolite treatment.

DISCUSSION

In treating mesophilic supernatant liquor with chemicals to promote clarification and separation of sludge of reasonably low volume, it was found that such treatment could be made effective if the proper chemical were employed in the correct proportions for a given liquor. Treatment with ferric chloride alone gave good clarification when the dosage was adjusted. However, the acid character of the iron salt released CO_2 from the bicarbonates present and caused the sludge formed to float. In practice this would not interfere as the clear liquor could be drawn as readily from the bottom of a tank as from the top. Overdoses of chemical caused the sludge layer to divide, which is undesirable.

The addition of sufficient sulfuric acid to partially neutralize the alkalinity prior to the application of $FeCl_3$ did not materially aid the process. When enough acid was used to equal the alkalinity, clarification could be obtained with half the amount of $FeCl_3$. The sludge volume was reduced, probably because more of the iron formed an organic complex rather than the hydrate, formed when alkalinity was present. However, this treatment did not prevent sludge separation and the acid released sulfides and other odorous substances which were decidedly objectionable.

Sodium hydroxide in conjunction with ferric chloride gave good clarification and no separation of the sludge, all of which settled to the bottom. The quantity of caustic added was sufficient to convert the bicarbonate to carbonate and prevent the release of CO_2 when the acid

iron salt was added. The dosage of $FeCl_3$ was not materially reduced. The main difficulty experienced with this treatment was the formation of a huge sludge volume consisting mainly of highly hydrated iron oxide. When good clarification was obtained the sludge volume amounted to as much as one-third the total liquor volume. A disagreeable odor was given off after caustic treatment.

By far the best results were obtained by the addition of lime with ferric chloride. Using 1,200 p.p.m. of lime, the coagulant dose could be cut from 25 to 50 per cent. Sludge settled to the bottom of containers rapidly and compacted readily. The total volume for the dosage producing good clarification was about 10 per cent of the total liquor volume in one hour. The character of the liquor was not radically changed except that the odor diminished in intensity.

This method of treatment combined the advantages of the caustic-ferric salt treatment without exhibiting the disadvantages. The insoluble calcium carbonate formed did not cause such a voluminous hydrate floc development as the caustic, but did serve in preventing the release of CO_2 which causes sludge flotation.

The substitution of alum for ferric chloride led to rather unsatisfactory results. In order to obtain fair clarification with alum alone or alum plus accessory chemicals 500 p.p.m. as aluminum was necessary. Sludge volumes were large except when acid was used. The explanation of this is that the alum did not cause good flocculation under acid conditions and its presence in large quantities in solution was evident. The best clarification was obtained when part of the alkalinity was neutralized with sulfuric acid. This is one characteristic in which the clarification of supernatant liquor by alum followed that of water or sewage. However, even this treatment did not allow an appreciably lower alum dosage and did not preclude alum from solution.

As the lime-ferric chloride appeared to be the best method of treatment of supernatant liquor the work on this was extended with the hope of improving the results. Lime water was compared with lime suspensions for effectiveness in clarification, both with and without $FeCl_3$. It was found that good clarification could be obtained with lime alone, but addition of lime in solution led to remarkably better clarification than did the use of a lime suspension. The reason for this may be the formation of calcium carbonate around the particles in suspension, preventing their solution and hence their activity on dispersion through the liquor. Although the results with the lime water were remarkable, a disadvantage is the quantity of water necessary because of the low solubility of lime. The large sludge volume, which generally amounted to one-quarter of the original volume of liquor, may be undesirable under certain conditions. Compacting appeared to be very rapid and experiments which will be reported later showed that considerable further compacting took place after the one hour of settling used in these runs.

Bentonite suspensions were found to be quite active in clarifying supernatant liquor. Of the three liquors employed for experiment two

required 1,450 p.p.m. and the other 580 p.p.m. Bentonite to produce good clarification. This clay appeared to form a single floc mass which shrank on standing, leaving a clear liquor on top. This shrinking took place rapidly, leaving sludge volumes of 8.5, 11.5 and 11.5 per cent, respectively, of the total liquor volume in one hour. The volume of sludge was in general in proportion to the quantity of Bentonite added.

Calcium chloride did not prove to be an aid to clarification of supernatant liquor with alum or ferric chloride. The only effect it appeared to have was to increase the sludge volume. This action may be due to the raising of the specific gravity of the liquor, making the sludge lighter in relation to it.

The attempts to remove iron-salt consuming substances with zeolite, thereby lowering the amount of ferric chloride necessary to clarify the liquor, failed. The ammonia-zeolite used removed ammonia but not the amino-ammonia compounds which Genter (1) believes to be responsible for the coagulant consumption.

Conclusions

1. Mesophilic supernatant liquor could be successfully clarified with ferric chloride.

2. Application of sulfuric acid, both sufficient to neutralize part of the alkalinity and all the alkalinity, did not greatly reduce the coagulant dosage and set up undesirable reactions.

3. Caustic soda employed with $FeCl_3$ prevented flotation or separation of the sludge, but did not appreciably reduce the coagulant dosage. Sludge became voluminous with this type of treatment.

4. Lime reduced the coagulant demand considerably, gave good clarification and a compact, rapidly settling sludge.

5. Addition of lime water gave better clarification per unit amount added than did lime in suspension, both with and without $FeCl_3$. The higher the lime dosage the lower the quantity of $FeCl_3$ necessary.

6. Alum alone and with acid, alkali, or lime did not appear satisfactory for treatment of the liquor.

7. Bentonite gave good clarification with rapid sedimentation and compacting of the sludge.

8. Calcium chloride was detrimental to the treatment with $FeCl_3$ and alum.

9. Pre-treatment with an ammonia zeolite did not lower the dosage of $FeCl_3$ necessary for clarification.

Summary

In studies on clarification of supernatant liquor from thermophilic and mesophilic digestion, a number of chemicals in varying quantities were tried, including ferric chloride, alum, lime, sulfuric acid, chlorine, Bentonite, zeolite and combinations of chemicals. Volume and character of sludge, turbidity, odor and color of liquor were observed.

Thermophilic supernatant liquor could be treated with acid and

coagulant to produce a good floc, rapidly settling, and a compacting sludge and clear liquor. Chlorine reduced odors, but when coagulants or coagulant aids were added odor returned, unless the chlorine demand was satisfied.

Mesophilic supernatant liquor could be clarified with most of the chemicals and combinations thereof employed in the coagulation of sewage and in sludge dewatering. Some of the methods were not particularly advantageous because of the amount necessary to obtain results, the volume of sludge formed, flotation of part of the sludge and odor production. Ferric chloric and lime, lime alone and Bentonite yielded the best results. The application of lime in solution was found to be much more effective than when a suspension was used.

Both thermophilic and mesophilic supernatant liquors could be readily clarified with lime amounting to 10 to 15 pounds per 1,000 gallons, in conjunction with ferric chloride amounting to 4 to 6 pounds per 1,000 gallons of liquor.

REFERENCE

1. A. L. Genter, "Adsorption and Flocculation as Applied to Sewage Sludges," *This Journ.*, 6, 689 (1934).

INCINERATION OF SLUDGE—SOME GOVERNING PRINCIPLES *

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It is proposed in this paper to discuss the subject of incineration from the standpoint of design. The drying and incineration of sewage sludge as an objective is new. The group of principles which have been gathered together and directed toward the solution of the problem is individually old.

The Problem

We may list four objectives in the disposal of sewage sludge:

Adequateness. The primary object is to take objectionable substances and to change their characteristics so that they are no longer creators of nuisance.

Cleanliness. This must be accomplished without nuisance, either from odor or dust.

Economy. These things must be done at low cost. This involves the creation of a simple system which will not require premium labor, excessive maintenance, or large quantities of supplies.

Flexibility. A unit must be provided which will be available on short notice for full load operation, which will be able to deal with any substance delivered to it for destruction, within the practical range, and to handle anticipated load fluctuations with facility. To serve the sanitary field well, we must handle any and all sludges.

The Principal Divisions of the Problem

It is obvious that a wet substance cannot be burned until all of the moisture has been dissipated. Drying must precede incineration. Such being the case, any system for incineration incorporates both a drying and a burning function. The salient elements composing the balance of the problem, which will be discussed at least briefly, are:

Thermal relations.

Combustion and the furnace structure.

Preheater application.

There are many other elements which engage the designer's attention such as burners, ash handling, duct velocity, automatic control, etc., which are entirely too detailed in their scope to be of great general interest at this time.

Thermal Relations.—Drying and incineration of sludge involves essentially a series of interchanges of heat. The heat balance, basically, recognizes the two sides of the ledger: profit and loss. The

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profits, or gains, are from two sources (1) the heat of the sludge and (2) the heat derived from supplementary fuel, if any be required. The losses are many but may be broadly divided into two types: (1) inherent and (2) preventable. The former are: hydrogen loss, radiation loss, sensible heat in ash loss, and moisture loss. The latter are: stack losses and combustible in refuse loss.

Radiation has been included among the inherent losses, inasmuch as suitable insulation brings it down to such a small figure that it ceases to be of much interest to the designer as a focal point for savings. It is inherent that the heat units required to evaporate water in sludge increase as the moisture content increases. Combustible losses are trivial in a properly designed system. There remains but one item among the controllable debits: the stack loss. It should be accorded the closest study as it is a complex item which correct design can influence in a pronounced manner. Its control involves many things, including the thermal cycle selected as well as the furnace design.

The Stack Loss.—For given conditions of operation the stack loss is governed by three principal elements: (1) the weight of gases leaving the unit, (2) the temperature of gases leaving the system and (3) specific heat of stack gases. The last is directly related but its variation is small and it is essentially beyond design control.

Let us consider the first two items, weight and temperature. The weight of gases leaving the unit, per unit of fuel burned, depends upon the number of pounds of air introduced into the system per pound of fuel. The moisture introduced into the system is also found in the stack gases but the designer has no control over the quantity. It is an old tenet in combustion work, well known to many here, that the excellence of a combustion process is measured inversely by the amount of air used, over and above that required for complete oxidation of the fuel. Greater amounts of air serve merely to carry away valuable heat, which may require replacement by use of supplementary fuel at considerable cost, or other expedients.

At the same percentage of excess air the temperature of gases from the combustion of two widely different fuels is essentially the same. One fuel is not "hotter" than the other. If the gas is hotter, it follows that excess air has been reduced for the one which we may loosely and erroneously consider hotter. Such a condition of temperature could

TABLE I.—*Design conditions*

Sludge Filter Cake per Hour, lbs.	4,000
Percentage Moisture	75
Percentage Volatile Combustibles	60
Sludge Dry Solids per Hour, lbs.	1,000
Sludge Heat Value per Pound, B.t.u.	6,000
Hours Operation per Year (16 hrs.—300 days)	4,800
Hydrogen Content of Combustible, %	8
Cost of Oil, per Gal. (150,000 B.t.u.), cts.	5
Cost of Power, cts. per kw. hour	2

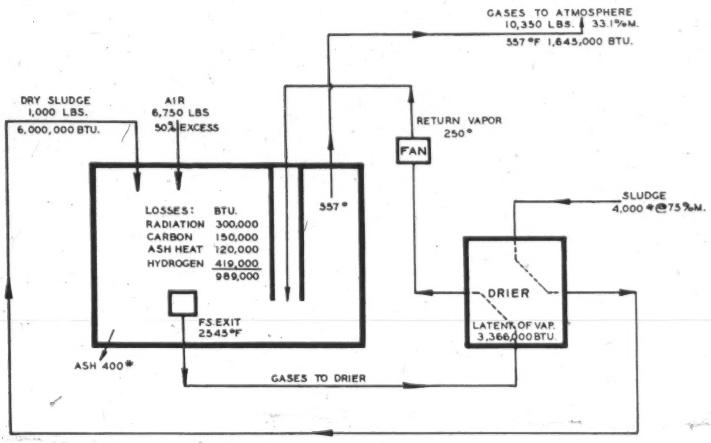

FIG. 1.—Basic elementary incineration cycle CE-Raymond system.

occur if air quantity were maintained constant, and additional heat units, as from oil, were added.

For the sake of clarity, the relations existing between the factors of the problem will be studied with reference to a set of nominally selected design conditions. These are shown in Table I and Fig. 1, which also shows the heat and quantities in balance. This has been set up with the requirement that the apparatus shall not require supplementary fuel. The heat balance (Table II) shows that an efficiency

TABLE II.—*Heat Balance*

Gains	
From Burning Sludge, B.t.u.	6,000,000
Total Credits	6,000,000
Losses	
Inherent	
Latent Heat of Vaporization, Sludge Moisture, B.t.u.	3,366,000
Radiation	300,000
Sensible Heat of Ash	120,000
Hydrogen Loss	419,000
Preventable	
Sensible Heat of Stack Gases	1,645,000
Unburned Combustible	150,000
Total Debits	6,000,000

requirement of 56.1 per cent is dictated. That such a requirement is practical will be demonstrated.

The sensible heat of the stack gases has been arrived at by difference. If the heat input to a system is established and all losses except

one evaluated, then the unknown loss must be the difference of the gains and the losses.

The heat balance may be dismissed with the single observation that the only loss of consequence captioned "preventable" is the stack loss, amounting to 27 per cent. Just how a preventable loss deserves to be so named when it is dictated by such a firm principle as stated above will develop.

Fig. 1 depicts a basic elementary system and shows the flow of materials with essential quantities and interchanges of heat in balance. A system for incineration based upon this diagram will not function in accordance with all of the desirable requirements set forth above. It will be economical but unacceptable inasmuch as it has been definitely proven that all gases and vapors arising from the drying and burning of sewage sludge and similar materials of organic origin, must be passed through a temperature zone where a temperature of not less than 1,300° F. exists.

On the question of nuisance there are two serious shortcomings: first, the gases which have been in contact with the sludge have not been elevated in temperature to the deodorization point of 1,300° F., and second, there is no provision for removal of fly ash from the escaping gases. Third, as far as flexibility is concerned, the apparatus would be limited to a narrow range of permissible heat and moisture content of sludge. The temperature of the gases to the atmosphere, 557° F., has been computed from the weight, composition, and heat content of the gases. If the heat content were to drop to below about 5,000 B.t.u. per lb., supplementary fuel would be required. There is no such provision. A similar necessity would exist if the moisture content of the sludge were increased to about 79 per cent. Allowable heat range would be from 5,000 to 6,000 B.t.u. while moisture range would be from 75 to 79 per cent, the one changing while the other is held at design value. These ranges are too narrow to warrant a claim of flexibility. The basic elementary system is impractical since it lacks, first, dust collection apparatus, second, means to supply added heat to make up deficiencies, and third and most important, will not be odorless.

The Economical Attainment of Deodorization Temperatures.—Two methods are available for deodorization by temperature. An oil burning system may be installed in the stream of gases to be deodorized, such that their temperature would be raised, or a preheater can be installed to recirculate heat, maintaining the same system exit temperature, as shown in Fig. 2, namely 557°, while the temperature entering the preheater is maintained at 1,300° F., a safe value for deodorization by temperature. Consider first the method by combustion of fuel:

The problem is to increase 10,350 lb. of gas from 557° to 1,300° F., requiring about 2,460,000 B.t.u. per hour. This requires the combustion of at least 17.55 gallons of oil per hour at an annual cost of $4,210. Capitalizing this expenditure at 15 per cent, an outlay of $28,000 could

be made with justification to avoid this high operating cost. The sum is a substantial proportion of the total cost of such a unit.

Consider next the method for deodorization by preheating apparatus. The same effect is obtained, except that the amount of heat required, 2,460,000 B.t.u., will be obtained by recirculation. With a conservative transfer rate of 3 B.t.u. per sq. ft. per hour per deg. F. mean temperature difference, a preheater of 1,950 sq. ft. will be required. Together with the necessary forced and induced draft fans such an addition to the elementary apparatus would involve an expenditure of $5,900. The fixed charges at 15 per cent would be $885. The added power at 2c per kw. hr. would add $860 to the operating costs, giving

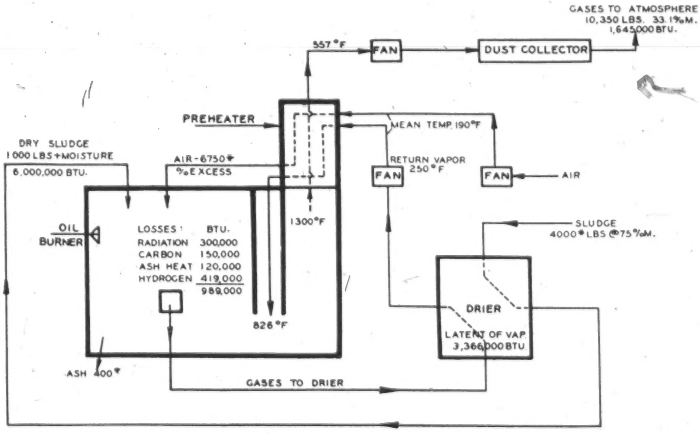

FIG. 2.—Incineration cycle CE-Raymond system.

a total of $1,745. Capitalizing this expenditure at 15 per cent as before, we have a value of $11,600.

To compare the two methods, the relative capitalized costs of $28,000 against $11,600 may be considered, while the annual operating costs are $4,210 against $1,745. The designer would not hesitate long in arriving at a selection of method. The preheater is not only indicated but demanded by considerations of economical design and operation.

Fuel and Oil Costs.—It has been shown that a substantial saving in fuel has been made by the addition of preheater apparatus to furnish what may be descriptively termed "circulating fuel." The mere addition of the preheater at its definite cost has not accomplished the desired result; it has been necessary to use additional power as well. It follows that the sum of cost of power plus cost of oil for one expedient must be compared with the same summation for the second expedient. The selection of method can not be condemned because of higher power

cost because such a procedure would leave out of account the greater gain effected by reduction of fuel cost.

The elementary basic system which was first advanced (Fig. 1) was found to have three shortcomings: addition of supplementary fuel burners and dust collecting apparatus follows along familiar lines so that we need not do more than add these items without discussion. Means for achieving proper deodorization have been selected as shown in Fig. 2.

Furnace Design.—A furnace is an enclosure of suitable size and shape for the combustion of fuel. It must work at an economically high temperature which will be near the fusing point of the ash, with a margin of safety. If the average furnace temperature greatly exceeds the fusing point of the ash, slagging takes place and seriously impairs ash removal, causing also high refractory maintenance. On the other hand, if the construction is such as to contain metallic elements exposed directly to the radiant heat of combustion the allowable temperature must be limited to this consideration and serious difficulty may be experienced in keeping the preventable stack loss at a low figure, because of the necessity for introduction of a high percentage of excess air.

Table III gives average furnace temperatures and stack temperatures for various values of excess air.

TABLE III

Excess Air, Per Cent	Furnace Exit Temperature	Stack Temperature	Exit Gas Weight, lb./hr.
50	2545° F.	557° F.	10,350 lbs.
100	1965	484	12,600
150	1670	430	14,850

In order to avoid confusion, the tabulation has been prepared to cover the elementary basic cycle of Fig. 1, which did not include the use of a preheater for deodorization. The design fundamental which will next be discussed, namely, the influence of allowable furnace temperature on stack loss, is present also in like measure in the final cycle shown in Fig. 2. The addition of heat to the air for combustion raises the temperature in the furnace. If we assume, as being roughly in accordance with practice, that one-third of the 2,460,000 B.t.u. per hour necessary for deodorization was conveyed back by air for combustion, the furnace temperature for 50 per cent excess air would rise to 2,955° F. It is apparent that a structure must be designed which will withstand high temperatures. If it will not, the quantity of excess air must be increased to avoid damage to the furnace. If this be done, larger weights of gases are handled at lower temperatures, as shown in Table III. This rise in temperature can also be offset by allowing larger quantities of moisture to pass to the furnace, increasing the weight of heat carrying means. The following of this expedient, however, requires a crisp division between drier and furnace.

Suppose the furnace structure requires that the temperature be held below 1,965° F. The deodorization process must be carried out on 12,600 lb. of gas per hour which must be raised to 1,300° F., from 484° F., instead of 10,350 lb. from 557°. It is apparent that a larger preheater will be needed and that far greater amounts of power to circulate gas and air will be needed. These heavy penalties are incurred because the furnace structure is not adequate for the higher temperatures dictated by economy. Instead of recirculating 2,460,000 B.t.u. per hour, a requirement of 3,170,000 B.t.u. per hour is indicated. This is an increase of 28 per cent in the air heater duty, and at least that much in operating cost and evaluated allowable first cost. The sum of $1,740 rises to $2,230 for operation with the economical air preheater method of deodorization. Corresponding evaluated allowable first cost rises from $11,600 to $14,850. Operating cost using fuel to deodorize jumps from an anuual cost of $4,210 to $5,390 with evaluated allowable prevention cost rising to $36,000. These figures indicate the importance of low excess air to effect desirable economy, and as allowed by rugged furnace structure.

In order to withstand high temperature, various features of a furnace need to be considered. First (and this requires but little exposition), good materials must be used. Second, adequate expansion must be provided in refractory faces and in the juncture of the furnace bounding surfaces. Third, the use of metallic supports for arch refractory must be employed when such arches are disposed over large areas. Lastly, metallic parts requiring large volumes of excess air for cooling should be excluded.

Among the necessary features for an incineration system, the element of flexibility was listed. So far, we have considered flexibility only in the light of ability to take and to handle the rather indefinite quantity and quality of sewage sludge. There is another important element. When a unit is needed for service, it, as a rule, is needed promptly. The very elements which contribute to a furnace structure to enable it to withstand high temperature, contribute also to the ability of the structure to withstand rapid heating and cooling. The furnace used in the CE-Raymond system can be put on a full production basis within half an hour from a cold condition. The question is mainly one of adequate expansion facilities and ability to expand unequally without structural damage. A sprung arch cannot be treated in this fashion.

Conclusions

It has been possible in this paper to cover but a small part of the subject of design. A host of other matters must be solved. Many of these attendant problems cannot be technically investigated but must be dealt with by trial and error in field experiments. It can be said, however, that existing methods and those not yet at hand must have a sound thermal basis. Possessing this, a system may or may not be a success; lacking such a basis, no method can succeed.

In conclusion, stress should be placed upon the following salient features:

(1) The problem should be approached in the full light of yesterday's analogous activities with a judicial use of their teachings.

(2) The objectives of the designer are four-fold; his design must be adequate, clean, economical and flexible.

(3) Close study of a proposed system involves the building up of the body on a sound heat-balance as a framework.

(4) An adequate furnace design is essential to an economical, flexible system.

(5) A design has been traced in an elementary way as a means for disclosing the logical background of an existing system.

(6) Economical operation dictates the use of heat recovery apparatus.

(7) The true measure of judgment in the use of supplies requires that their sum, rather than their individual magnitudes, shall be considered.

DIGESTION EXPERIENCES AT AURORA, ILLINOIS *

By Walter A. Sperry

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The operation of sludge digesters at the Aurora plant began to be a problem in 1936. Prior to that date, we had experienced six years of very uniform and satisfactory operation. We had an evenly distributed sludge load to the digesters and a uniform gas production which approximated 12 million cu. ft. per year. During these six years digesters were discharged to the beds from two to four times per year, which gave ample drying time and low removal cost.

The year 1936, however, was a turning point, with a marked increase in the sludge volume, which increase continued through 1937 and 1938. In 1937 and 1938 not only did the primary sludge volume increase but there was an added load of 1,200 pounds per day of secondary sludge to be digested. Gas increased to 18 million cu. ft. per year, digester cleaning periods increased to six per year. Several times during this period critical impasses occurred necessitating such undesirable stunts as dumping raw sewage or digested sludge to the river, and having the clarifiers uncomfortably filled with supernatant sludge. This included expensive winter cleaning of the sludge beds. The general history of this developing condition has been recorded through April, 1937, in the July issue of *Sewage Works Journal* for 1937.

During 1937 it appeared more and more evident that the adoption of the two-stage type of digestion would much relieve the problem. This decision was definitely concurred in by the state authorities, Dr. Fischer of the Dorr Company and the several engineers who were acquainted with the situation. It appeared that a larger amount of solids could be handled in two-stage digestion than in single stage, without the "ballooning" effect which the larger volumes of gas discharge appeared to produce. It also appeared that if the plant were rebuilt into a two-stage type with one digester assigned to first stage and two digesters to second stage, the ability to discharge sludge from the second stage would be improved by reason of having five drying beds per digester in place of three and one-third beds per digester, under the single-stage plan.

As a preliminary, a series of two-stage experiments were set up and operated over two and one-half months. These digesters were made of five-gallon cans and were operated under a daily charging plan with normal plant sludges in amounts mathematically proportional to the plant load for that day. The results of these experiments were normally characteristic of two-stage digestion as to the degree of digestion, volume of gas produced, ratio of gas from first and second stage, quality

* Presented at the Eleventh Annual Meeting of the Central States Sewage Works Association, Neenah-Menasha, Wisconsin, October 14, 1938.

of supernatant liquor and all other characteristics. This experimental work is reported, in detail, in the plant annual report for 1937.

An engineering study of the digester layout indicated that a few very simple mechanical changes would easily convert our three fixed-cover type of trussed Dorr digesters to the two-stage type, and that they would operate as regularly planned two-stage digestion.

A typical transfer box was built on the roof of the first digester and the supernatant overflows of the other two digesters, reserved for second stage, were slightly lowered. The inspection manhole of the first digester was sealed and elevated two feet. The gas dome of the first digester was similarly raised and a 5,000 cu. ft. per hour meter was substituted for the existing 1,500 cu. ft. meter. The 2-in. gas lines from the first stage digester were enlarged to 3 inches. With this arrangement, on discharge of primary sludge to first stage, transfer sludge automatically flowed to the second stage digesters and supernatant liquor discharged back to the clarifiers. The work was done by the plant personnel and the total cost of the change was about $1,400. Moreover, the whole system was so set up that we could operate the plant either single or double stage, without change of piping, so that we had greatly increased plant flexibility at a very low cost.

Two-stage operation formally began September 1, 1937. All primary and secondary sludge was applied to the first stage digester. Hydraulically, our rearrangement worked satisfactorily. Digestion proceeded normally as did the gas production. The gas ratios produced in first and second stage were as predicted by the laboratory experiments.

The first few months of operation were distinctly disappointing, however, in the fact that the one thing we sought to correct, namely, the lengthening of the storage period in the digesters, failed to materialize. In the five-month period between September 1 and February 1, 1938, we had to discharge the digesters three times. During January we were faced with the necessity, during a high river period, of discharging a quantity of digested sludge direct to the river, to get by. This was definitely disconcerting.

In the meantime, however, a new angle developed. In a study of the per cent solids in the primary sludge to the digesters our attention was directed to the fact, heretofore unnoticed, that the solids had gradually declined from 5.5 or 6.0 per cent to 3.5 per cent. This eventually proved to be the saving clue. Studies developed the previous year as to the volume of sludge occupied at various percentages of dilution, and used to check the accuracy of the Aurora Tipping Bucket Sludge Meter, indicated at once that the volume of sludge discharged to the digesters had been gradually increasing and at an alarming rate. To illustrate, a 6.0 per cent sludge occupies 270 cu. ft. per 1,000 lb. of sludge while a 3.5 per cent sludge occupies 470 cu. ft., an increase of 74 per cent.

On studying the significance of this fact we realized that plant operation since May, 1933, had been definitely in error. We had failed to realize the significance of the fact that there is a decided relationship between the concentration of solids to a digester and its storage ca-

pacity. Prior to the introduction of the sludge meter, sludge control had been fairly good, but "blind," since the time of pumping was largely controlled by an arbitrary number of minutes. After the introduction of the sludge meter we had full "sight" control of the quality of sludge. Orders were to pump sludge until no more sludge appeared since we had a perfect chemical sample available and knew the exact volume, the emphasis being laid on the desirability of keeping the clarifiers free of sludge blanket. In the meantime the pumping pe-

TABLE I.—*Character of sewage: 1931–1938 (Through September)*

Year	Flow M.g.d.	Suspended Solids		Per Cent V. M. in Sludge	Total lb. Sludge per Day	Total lb. V. Mat. per Day.	Per Cent Increase of Sludge over 1931
		Raw P.p.m.	Clar. P.p.m.				
1931	5.759	167	108	70.6	3,500 Pri. only	2,470	Base
1932	7.202	140	60	67.5	4,000 Pri. only	2,700	14.3
1933	6.580	130	67	67.0	3,500 Pri. only	2,340	No incr.
1934	5.596	184	71	72.1	4,070 Pri. only	2,930	16.3
1935	7.213	148	63	67.0	4,220 Pri. only	2,830	20.6
1936	7.132	149	63	71.6	5,440 Pri. only	3,900	55.4
1937	6.340	168	70	65.5	7,340 P. & S.	4,840	109.6
1938	7.530	153	61	58.9	8,000 P. & S.	4,670	128.8

Sludge data as related to digester storage capacity

Year	Per Cent Total Sol.	Min. Pumped per Dig.	Per Cent Incr. over 1931	G.p.m. Sludge Pumped	Cu. Ft. Sludge per Dig.	Per Cent Incr. over 1931	Days to Fill 1 Dig.
1931	6.3	60	Base	40	318	Base	128
1932	5.6	67	11.6	40	360	13.2	113
1933	5.5	69	15.0	40	370	16.3	111
1934	5.2	79	31.6	40	413	29.8	99
1935	4.6	111	85.0	34	488	53.3	84
1936	3.6	158	163.0	35	747	134.8	55
1937	3.7	171	185.0	40	1,070	236.0	38
1938	5.2	129	114.9	37	840	164.0	49
Probable condition in 1938 if a 3.7 per cent total solids sludge had been carried:							
1938	3.7	187	212.0	40	1,170	267.0	35

riods gradually increased. This increased the length of agitation period in the digesters. The thinner sludge produced, in turn, caused a bulking effect in the digesters. It is quite possible, therefore, that had this error been discovered sooner or had we maintained the more concentrated sludges of the years prior to 1933 we might not so soon have considered the necessity of adopting two-stage digestion.

Table I presents sewage and sludge data as related to digester storage capacity, from January, 1931, through September, 1938. It clearly shows the above situation. For comparative purpose it is based on single-stage operation and indicates the effect of sludge concentration

on the rate of filling one digester. The flow and quality of sewage remained much the same. The increase in pounds of sludge to the digesters is plainly indicated. The pounds of volatile solids bears a consistent relation to the quantity and quality of sludge produced. The marked jump in sludge quantities in 1937 and 1938 is due to the addition of secondary sludge, which began January 1, 1937.

Based on the 1931–33 poundage the sludge handled in 1938 shows 129 per cent increase. The significant part of the table is indicated in the per cent total solids in the sludge, which averaged 5.8 per cent from 1931–33 inclusive. From 1934 to 1937 it dropped, by successive steps, from 5.2 to 3.7 per cent. In 1938 it was brought back to a 5.2 per cent content by correcting the operating error, discussed above.

This change was easily brought about. The plows on the clarifiers, which had never had any maintenance work applied, were refitted with new bronze scrapers, the pumping periods were reduced from six to five and the minutes pumped were reduced materially and to a point where the clarifiers were maintained free from sludge blankets, as indicated by periscope tests. The cubic feet of sludge per digester decreased from 1,070 to 840 per day. The days to fill a digester increased from 38 to 49. The last line of Table I startingly indicates the comparisons had we maintained in 1938 the sludge quality of 1937.

The same principle, used to get a more concentrated delivery of sludge from the clarifiers, was applied to the secondary sludge, which was raised from a 3.5 per cent solids to a 6.0 per cent solids content.

Table II presents the history of the second-stage digesters before and after the correction of the primary and secondary sludge concentrations (February, 1938). It picks up the history of the second-stage digesters from the time of their beginning (September 1, 1937) and carries it through September, 1938. It falls into three natural periods.

The first period deals with the digesters between September and January, 1938, inclusive. During this period digester runs were short lived and no better than before two-stage operation. Operation was, therefore, definitely unsatisfactory. During this period, primary sludge averaged 3.8 per cent total solids, secondary sludge 3.5 per cent total solids and transfer sludge 2.9 per cent total solids. The total period of digester agitation caused by sludge pumping averaged 607 minutes per day. The sludge in the body of the digester and above the first foot, averaged 4.9 per cent total solids and occupied 336 cu. ft. per 1,000 pounds of equivalent dry sludge. This was the period immediately before our correction of sludge concentration conditions. Digesters were discharged to the beds three times and averaged but 49 days between discharges—a rate of seven discharges per year.

The second period between February and April, 1938, inclusive, marks the first turning point. The averages for this three-month period indicate marked improvements over the first period, due to the sludge content changes made in February. Primary sludge total solids increased from 3.8 to 4.8 per cent. Secondary sludge increased from 3.5 to 6.6 per cent total solids. Transfer sludge concentration remained

as in the first period. The digester agitation time caused by sludge pumping, during this period, dropped from 607 to 440 minutes and the concentration in the body of the digester increased from 4.9 to 6.1 per cent total solids. One thousand pounds occupied but 270 cu. ft. as

TABLE II.—*Second stage digester conditions before and after the correction of primary and secondary sludge solids concentration*

	Per Cent T. S. in Bottom of Dig.	Per Cent T. S. in Body of Dig.	Cu. Ft. Occupied by 1,000 lb. Sludge	Per Cent Total Solids			Min. Pumped/Day			Days Stored in Dig.*
				Pri. Sl.	Sec. Sl.	Trans. Sl.	Pri. Sl. to 1st Stage	Sec. Sl. to 1st Stage	P.-S. Sl. to 2nd Stage	
1937										
Sept.	—	—	—	3.9	3.2	4.2	567	106	673	
Oct.	6.5	5.8	283	3.3	3.3	2.9	450	114	564	39
Nov.	6.3	5.3	310	3.8	3.0	2.4	422	92	514	
Dec.	5.7	4.9	336	3.4	3.1	2.1	487	69	556	59
Jan. '38	5.0	3.7	444	4.6	5.1	3.1	675	55	730	50
Aver.	5.8	4.9	336	3.8	3.5	2.9	520	87	607	
1938 †										
Febr.	7.0	5.6	293	3.7	6.9	1.4	266	66	332	
Mar.	6.9	6.3	260	5.1	6.1	2.7	314	162	476	
April	7.3	6.4	257	5.5	6.8	3.3	405	106	511	80
Aver.	7.1	6.1	270	4.8	6.6	2.5	328	112	440	
1938 ‡										
May	—	—	—	5.5	6.0	2.0	397	89	486	
June	11.0	8.8	187	5.8	5.5	2.6	365	71	436	77
July	12.2	10.0	165	5.8	6.3	3.3	330	73	403	
Aug.	13.3	11.1	147	5.1	5.9	2.8	360	79	439	
Sept.	13.6	11.2	146	4.7	5.4	2.9	380	64	444	96
Aver.	12.5	10.2	161	5.4	5.6	2.7	366	75	441	

* Digesters discharged to beds in month shown. Figure indicates days retention since last discharge.

† February, 1938. Changed sludge pumping schedule, reducing both the number of pumpings per day and the length of each pumping period.

‡ April, 1938. Changed operating plan by withdrawing secondary sludge from the first-stage digester to the two second-stage digesters on alternate days.

against 336 cu. ft. in the first period discussed. The apparent marked improvement due to the more concentrated sludge and shorter time of pumping is indicated by the fact that the digester run for the discharge in April increased from an average of 49 to 80 days. This was the first definite indication of relief from our former condition and leads us to the further improved conditions as indicated in the third period, running from May to October 1, inclusive.

The second major change in operation was introduced in April by withdrawing the secondary sludge from first stage and pumping it directly to second stage, delivering it on alternate days to each of the two second-stage digesters. It was hoped that the more concentrated nature of the secondary sludge, which averaged 6.0 per cent total solids, would offset the approximate 3.0 per cent total solids in the transfer sludge and further improve digester conditions. The effect was marked. The primary sludge leveled off at 5.4 per cent total solids, which was a return to the conditions prevailing in 1931–33. Secondary sludge averaged 5.6 per cent total solids and the total minutes pumped to second stage remained at 441. The sludge in the bottom layer increased from 7.1 per cent total solids to 12.5 per cent, and the sludge in the body of the digester increased from 6.1 per cent total solids to 10.2 per cent and occupied but 161 cu. ft. per 1,000 pounds as against 336 cu. ft. in the first period. The days between the two digester discharges for the period averaged 86 days, which approached our old rate of approximately four discharges per year. Thus as between the first and the third period under study the volume occupied by 1,000 pounds of sludge decreased by half while the days retention by the digesters doubled. Moreover, the return to 10.2 per cent total solids in the body of the digester made the sludge quality in the second stage equivalent to the more satisfactory conditions in 1931–33. The slightly greater number of digester discharges to the beds was the natural effect of the increases in the solids handled in the earlier years against the present period.

It might be interesting to describe the first-stage digester for the purpose of recording our experience in remodelling existing apparatus. In regularly designed two-stage digestion, the first-stage digester is usually equipped with several stirring devices, the effect of which is to destroy zoning effects in the digester and make uniform the character of the transfer sludges.

In planning for the Aurora layout Digester No. 1 was the only one that lended itself to use for first stage, partly because it was on the end and partly because this particular digester had a pipe-and-valve connection from the sludge sump in the bottom, projecting through to one of the clarifiers. No use had ever been made of this valve and we are uncertain as to the original intent of the designers. The existence of this valve and pipe gave us a bottom outlet for the transfer sludge to the transfer box at the top and simplified the transfer piping from this box to the two second-stage digesters. It also happened that these digesters were originally equipped with bottom plows and a scum breaking arm at the top. In Digesters No. 2 and 3, assigned for second-stage duty, both the bottom plows and the scum-breaking arms were in good working order. Some years ago, however, the scum-breaking arm on the first digester was broken and it was repaired twice, but the repair was a failure. After that no effort was made to restore the scum-breaker arm to working order. For a period of years this digester had worked as satisfactorily as the other two digesters without scum-

breaker arms. Scum formation gave no more trouble in this digester than in the other two, nor did scum appear to accumulate to a greater extent. During the digester cleaning periods the scum was dropped, washed out and picked up again and generally tended to remain about 2 ft. in depth. Consultation with the Dorr Company indicated that we would quite likely get satisfactory operation from this digester functioning as first stage without the need for stirring apparatus. Moreover, it was understood that this could be added at any later date if this problem arose.

Our subsequent experience indicates that we will not need stirring. As much as 77,500 cu. ft. of gas has been discharged from this first-stage digester in a twenty-four hour period, which was a release of 31 cu. ft. per sq. ft. of area. This gas collected to the 4-ft. gas dome at the center without difficulty.

The contents of the digester, however, fell into three zones for several months. The top four feet consisted of a heavy, sticky, gummy scum layer approximating 15 to 20 per cent total solids content. Beneath this scum layer was an almost clear supernatant zone of varying depth, below which was a bottom zone averaging 6 to 8 per cent total solids.

The general plan was to so operate this first stage as to retain in the digester as much of the solids as possible. If we transferred normally from the bottom this meant a very heavy charge of transfer to second stage each day. Advantage was, therefore, taken of the thinner center zone through the use of a telescoping pipe, with slots in the side, enabling us to draw sludge of about three per cent consistency from varying levels, for transfer. Sludge withdrawal was made once a week from the bottom to keep the transfer pipe from clogging and stoppage. The peculiar zoning effect is also indicated in the four-stage digestion plant in California.

Sometime after January, 1938, however, it was noticed that the heavy scum layer, noted at the top of the digester, had disappeared and that a fairly clear supernatant zone had taken its place. It was first thought that this shift of position of zones might have been due to a slump in gas production caused by rain dilution of the sewage. Later, however, we went back to a heavier gas production with gas as high as 55,000 cu. ft. per day from first stage, but as yet there has been no return to the heavy zone at the top. This experience, therefore, seems to raise a reasonable doubt as to whether the rate of gas release per square foot of area tends to cause bulking effects, as indicated in former discussions. It now appears that if the solids content of the tank are in sufficiently concentrated form the gas evolution may be high and that no bulking effect occurs due to the rate of gas release under these conditions.

With further reference to the 3.0 per cent transfer sludge at Aurora it is interesting to note that the record of the Battle Creek, Michigan, plant, with mechanical stirred first-stage digestion averages a 6.0 per cent primary sludge to first stage, but apparently due to mixing, trans-

fers an average of 2.5 per cent solids to second stage, which is a very thin sludge occupying 690 cu. ft. per 1,000 pounds of sludge. At the same time the supernatant to the clarifiers averages 1.5 per cent total solids. Judging from the Battle Creek and Cedar Rapids experience (Cedar Rapids has a settling tank in the supernatant line) it appears that concentration of solids in second stage is somewhat of a problem. The Aurora supernatant from second stage has averaged the normal supernatant quality of single stage operation, and runs from 0.30 to 0.40 per cent total solids.

Summary

Several conclusions seem to stand out clearly in this thirteen months experience with two-stage operation.

(1) We can not forebear pointing out the value of complete records. They add many hours to the daily routine but too often help solve existing problems to ever discontinue.

(2) This story of error in operation and its consequences emphasizes the need for daily attention to operating conditions and the continual interpretation of their meaning.

(3) There is a clear-cut emphasis on the relation between concentration of solids in a digester and the amount of agitation produced in the period over which sludges are discharged to the digesters, as indicated in the second period (Table II).

(4) There is an equally clear-cut emphasis on the relationship between the concentration of solids in a digester and the concentration of sludges applied.

(5) It is not clear which of these two effects is the more important, although one is a corollary of the other. If the sludges are kept concentrated the period of sludge discharge will be shortened.

(6) It was possible, due to local arrangements, for the Aurora plant to make use of its secondary sludge to correct conditions in the second stage. This was an important factor.

(7) It finally may be pointed out that experimental work on plant problems is always profitable. We might not have tried putting secondary sludge in the second stage had it not been for extensive experiments as to the digestibility of secondary sludge, either alone or in various combinations with primary sludge, and found that it worked equally satisfactorily in any combination.

ACTIVATED SLUDGE OXIDATIONS

I. EFFECT OF SLUDGE CONCENTRATION AND TEMPERATURE UPON OXYGEN UTILIZATION*

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The question of how much activated sludge, as measured by suspended solids, to carry in the aeration tanks is one upon which few sewage plant operators will agree. The problem is solved in most instances by the "trial and error" method, and eventually each operator finds a routine which will give him the results he desires. In some cases this routine is established within a few months time, while in others years may pass by without definite conclusions being drawn.

The need for research on this particular problem has been recognized for several years and the first detailed study was reported by Grant, Hurwitz, and Mohlman (1) in 1930. The results of their work, which was based on individual experiments performed on separate days, using pure oxygen in a special apparatus, showed that mixtures of activated sludge and sewage used oxygen in proportion to the weight of sludge that they contained. They also noted that high sludge concentrations seemed to remove the oxidizable material from the sewage rather rapidly and found that the rate of purification was not accelerated directly in proportion to the amount of sludge.

Voelker (2) has reported results obtained with a small experimental plant in which the activated sludge was allowed to increase in concentration to a value of 5000 p.p.m. in the aeration mix and then the solids were gradually decreased to 300 p.p.m. by wasting of the sludge. His results indicated that the efficiency of stabilization, as measured by the B.O.D. of the effluent, increased rapidly until a concentration of 2000 p.p.m. of suspended solids in the aeration tank was reached. Above 2000 p.p.m. the efficiency increased, but at a much slower rate. Efficiency of clarification, as measured by suspended solids in the effluent, increased rapidly until a concentration of 1200 p.p.m. of solids had been reached. Above this value the efficiency also increased, but much more slowly.

Ridenour (3) has reported a study similar to that of Voelker's which was made upon a plant treating about 1.2 million gallons of institutional sewage per day. His results check those of Voelker but the critical points determined were in the neighborhood of 800 p.p.m. of suspended solids, a value somewhat lower.

In the matter of the effect of temperature upon the rate of purification of sewage by activated sludge, Ardern and Lockett (4) were the first to report that lowering the temperature slowed down the process,

* Presented at the Eleventh Annual Meeting of the Central States Sewage Works Association, Neenah-Menasha, Wis., Oct. 13, 1938.

and that below 10° C. the process was greatly hampered. Experience with the activated sludge process of sewage treatment has indicated that no great difference in the character of the effluent produced seems to be traceable to changes in seasonal temperatures, the sludge seemingly being able to adapt itself to the changing environmental conditions. Viehl (5) has indicated that the rates of nitrogenous and carbonaceous oxidation by activated sludge were influenced differently by temperature changes. Nitrogenous oxidation is claimed to follow more or less closely the van't Hoff law, and the decomposition of the organic matter, or in other words, the carbonaceous oxidation is claimed to be influenced only slightly by temperature changes between 8° and 35° C. Bloodgood (6) in reporting studies made upon Indianapolis activated sludge, has found the rate of oxygen utilization to increase markedly and quite uniformly between 10° and 30° C.

Most recent developments in the treatment of sewage by the activated sludge process have had, as the main objective, the lowering of the aeration costs. Impetus was given to such attempts by the discovery that activated sludge-sewage mixtures do not use oxygen uniformly throughout the aeration period but, rather, use it very rapidly in the beginning with a tapering off in rate as the aeration period progresses. The practice of "Tapered Aeration," as proposed by Kessler, Rohlich, and Smart (7), has become quite widespread in its application in existing plants that were equipped to make the transfer and has also been featured in the design of some of the newer plants. The use of "Tapered Aeration" naturally raises the question of sludge concentration and its relation to the tapering of the air supply. Another question of importance in this respect involves the influence of changing temperature with changing seasons. Additional information on these two factors will no doubt be of value in the design of new plants and will also assist materially in the satisfactory operation of existing plants.

With the increasing practice of using some sort of instrument to study the oxygen utilization by activated sludge and activated sludge-sewage mixtures under laboratory conditions, it is becoming necessary to know the temperature coefficient for the rate of oxidation so that the laboratory results can be interpreted in terms of the conditions under which the plant is operating.

Early attempts to study these factors had indicated the futility of making studies on successive days with changing sludge and sewage and the importance of carefully controlling the temperature. As a consequence, provision was made for making simultaneous studies with the aid of four instruments. Some of the results obtained are presented in this paper.

Methods

All oxygen utilization studies on the effects of varying sludge concentrations and temperatures were made with instruments developed in this laboratory during the summer of 1937. The instruments employ

the use of diffused air in a closed circuit and measure the amount of oxygen used by a volumetric method. The instrument has been named the Oxy-Utilometer.

Figs. 1 and 2 illustrate the details of the instrument. In Fig. 1, *A* represents the rotary compressor from which the air, under pressure, travels to tube *B* where it bubbles through alkali solution to remove the CO_2. On leaving *B*, the air passes through the trap *C* to prevent mechanical entrainment of alkali. The air, freed of its CO_2, passes to diffuser plate *D* where it is broken up into fine bubbles, and, in its rise to the surface, agitates the mixture and at the same time supplies it with oxygen. The air, reaching the surface of the mixed liquor in bottle *E*, has lost some of its oxygen and has picked up a new load of CO_2, but it is again at atmospheric pressure. It now flows back to the compressor *A* by way of the wide tube *F* and the trap *G*. This movement of the air constitutes the cycle through which it is constantly recirculated. As oxygen is removed by the mix in *E* and the CO_2 produced is removed in trap *B*, the amount of oxygen in the air in the system decreases and the pressure drops. Such a change is indicated on the manometer *P* of the measuring device. To bring the pressure in the system back to normal, water is added from the burette *J* into the bottle *H* which is filled with pure oxygen, and an equivalent volume of oxygen is displaced through *N* into the circulating system to replace the oxygen used and maintain the same partial pressure relationship between oxygen and nitrogen.

Thus, by maintaining a constant level in the manometer by addition of water from the burette and by noting the time elapsing between readings on the burette, the rate at which oxygen is being used can be computed when the proper corrections are made for the volume of the sample in *E*, the temperature of the oxygen at *H*, and the barometric pressure.

When the bottle *H* becomes filled with water, the bottle is refilled with oxygen by displacement of the water with pure oxygen stored in the balloon *K* by opening or closing the necessary valves or screw-clamps at *O*, *P*, *R*, *L*, and *S*.

All of the apparatus indicated within the area *M* is immersed as completely as possible in a constant temperature bath.

Details of the Apparatus in Fig. 1

A. A rotary compressor operating at 450 r.p.m. and delivering approximately 0.25 cu. ft. of air per minute under a pressure of about 1.5 lb.

B. A large size Pyrex test tube containing 50 ml. of 3 per cent sodium or potassium hydroxide.

C. A distillation head similar to those used in free ammonia and Kjeldahl nitrogen determinations. Used solely to prevent mechanical transfer of alkali from *B* to *E*.

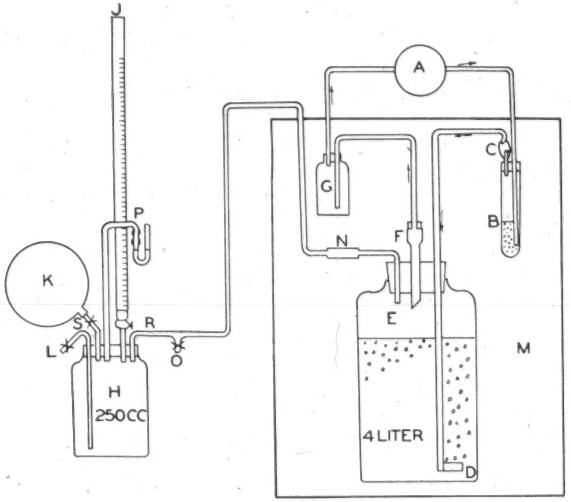


FIG. 1.—Detail of Oxy-Utilometer.

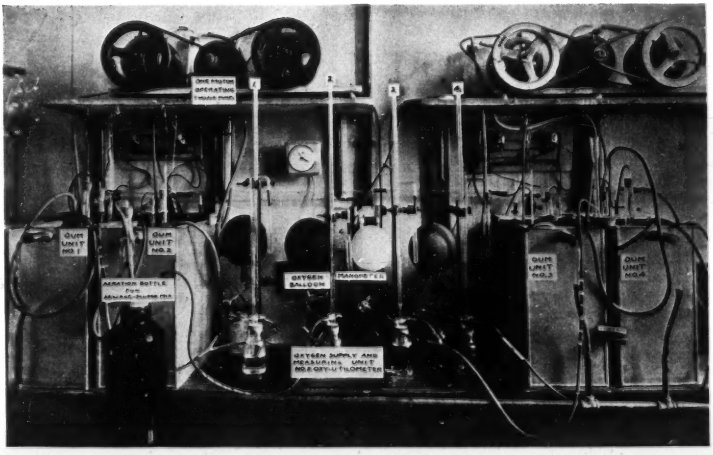


FIG. 2.—View of four Oxy-Utilometers used in making simultaneous oxygen utilization studies.

D. A home-made diffuser plate consisting of a piece of half-inch "Filtros" plate 1½ in. by 1¾ in. set in a holder made of copper and held in place by litharge plus glycerine cement.

E. An ordinary brown glass bottle of 4 liter capacity. (Sample used was 3,200 ml. in all cases.)

F. A short condenser tube with large bore to prevent restriction to flow of air by drops of liquid.

G. A small bottle, 500 ml. capacity, to act as a surge tank or compression chamber and also to protect compressor *A*.

H. A bottle of 250 ml. capacity to hold supply of oxygen and collect water added to displace the oxygen into the circulating system.

J. Burette or similar measuring device to determine amount of oxygen added or used.

K. A small rubber balloon to act as a low pressure storage tank for pure oxygen which is used to displace water in H with oxygen.

L. Tube reaching to bottom of H through which water displaced from *H* passes. Closed by screw-clamp.

M. A constant temperature water bath sufficiently large to contain the apparatus included within the area *M* of Fig. 1. The tank is fitted with a temperature controlling device capable of maintaining a temperature range of less than 0.1° C.

N. A special pulsation and diffusion muffler, constructed of alternate pieces of 6 mm. and 1 mm. glass tubing.

O. Opening to atmosphere which is used to finally close the system.

P. Oil manometer to indicate relationship of pressure within the system to atmospheric pressure and having a rubber connection to allow restriction by screw-clamp or other device to prevent oil in manometer being blown out when water in bottle *H* is being displaced by oxygen.

R. Rubber connection to allow closure as with *P*.

S. Screw-clamp to release oxygen reserve in ballon *K* to displace water in bottle *H* when it is desired.

The activated sludges used were obtained from two Wisconsin municipalities, *A* and *C*, and kept in good condition by feeding twice daily with sewage from city *A*.

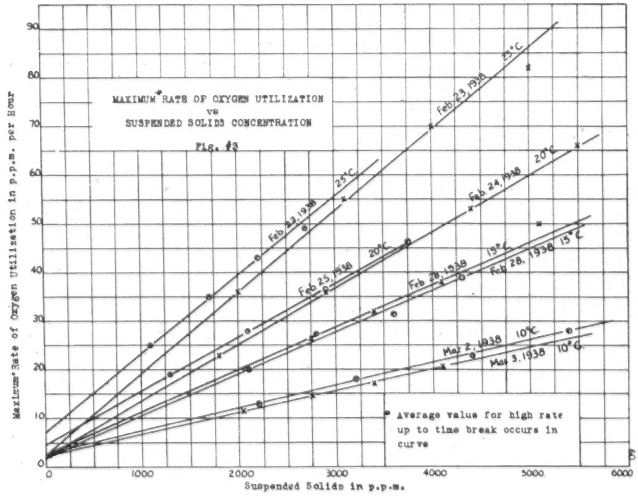
Simultaneous Sludge Concentration Studies.—These studies were made at each of the following temperatures; 10°, 15°, 20°, and 25° C. Two complete runs were made at each of the temperatures in the following manner: First the activated sludge and sewage were adjusted to the temperature at which the run was to be made. Then four different size samples of activated sludge were taken from the same supply and the volumes of the smaller portions were all made equal to that of the largest by the addition of distilled water, also at the proper temperature. The samples of sludge were next charged into the Oxy-Utilometers and equal volumes of a given sewage were added to each. In this manner, the same amount of food was added to each sample of sludge. Charging the last instrument was completed about six to eight minutes after the first instrument was charged.

Simultaneous Temperature Studies.—Simultaneous studies using identical activated sludge-sewage mixtures were made at 10°, 15°, 20°, and 25° C. Each sample of sludge and sewage was adjusted to the temperature at which the run was to be made prior to the time of charging the instrument. The total time elapsing during the charging process approximated thirty minutes and because of this rather long period, the instrument being maintained at 10° was always charged first.

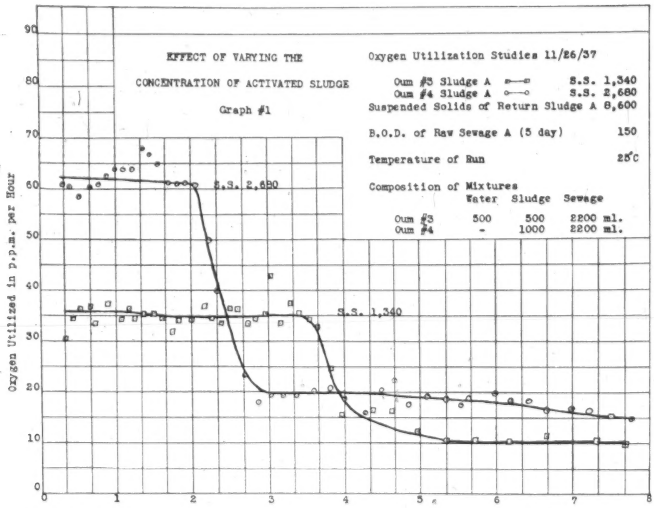
Experimental Results

A brief explanation of the graphs which show the experimental results is necessary. At the conclusion of each simultaneous run, the experimental data was plotted on a large scale graph and curves were drawn to correspond as closely as possible to an average of the experimental points. Graph 1 shows the results of a trial run on sludge concentrations using only two instruments. All experimental points have been inserted to show normal deviation from the curve and also the number and frequency of the experimental points determined.

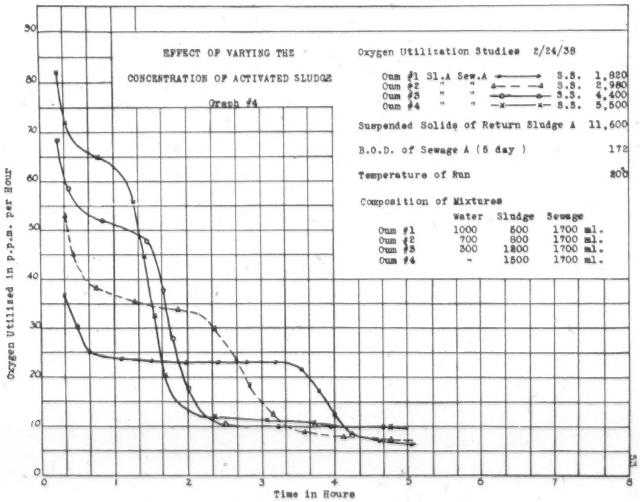
Simultaneous Concentration Studies (*Graphs 1, 4, 5, 9, 10; also Fig. 3*).—A total of ten simultaneous studies were made to study the

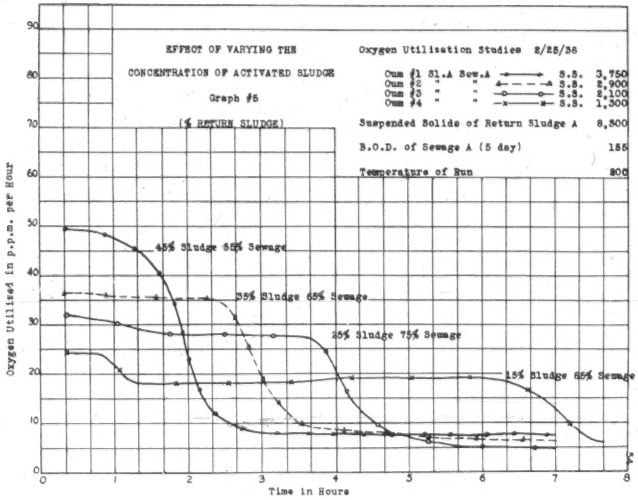

MAXIMUM RATE OF OXYGEN UTILIZATION
vs
SUSPENDED SOLIDS CONCENTRATION
Fig. #3
Maximum Rate of Oxygen Utilization in p.p.m. per Hour
Suspended Solids in p.p.m.
Feb 23, 1938 25°C
Feb 24, 1938 20°C
Feb 25, 1938 25°C
Feb 26, 1938 20°C
Feb 27, 1938 15°C
Feb 28, 1938 15°C
May 2, 1938 10°C
May 3, 1938 10°C
Average value for high rate up to time break occurs in curve

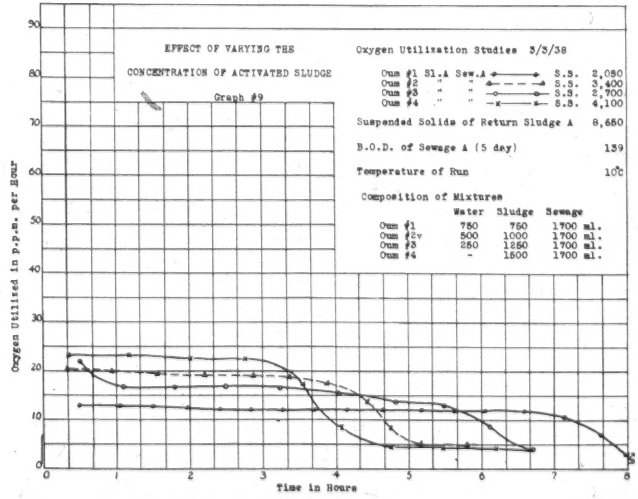
effect of the concentration of activated sludge upon the oxidation of sewage. Nine of the runs were made using Sludge A and one with Sludge C. All of the results obtained at the different temperatures with Sludge A were of the same character, consequently, only a few of them have been included in this paper (Graphs 1, 4, 5, and 9). They show definitely that the rate of oxygen usage increases as the concen-


EFFECT OF VARYING THE
CONCENTRATION OF ACTIVATED SLUDGE
Graph #1
Oxygen Utilization Studies 11/26/37
Oum #3 Sludge A S.S. 1,340
Oum #4 Sludge A S.S. 2,680
Suspended Solids of Return Sludge A 8,600
B.O.D. of Raw Sewage A (5 day) 150
Temperature of Run 25°C
Composition of Mixtures
Water Sludge Sewage
Oum #3 500 500 2200 ml.
Oum #4 - 1000 2200 ml.
S.S. 2,680
S.S. 1,340
Oxygen Utilized in p.p.m. per Hour

A brief explanation of the graphs which show the experimental results is necessary. At the conclusion of each simultaneous run, the experimental data was plotted on a large scale graph and curves were drawn to correspond as closely as possible to an average of the experimental points. In preparing the graphs for this paper, only the curves have been used because of the confusion that would be caused by numerous experimental points when plotted on the smaller scale. Graph 1 shows the results of a trial run on sludge concentrations using only two instruments, and the experimental points have been inserted to show normal deviation from the curve and also the number and frequency of the experimental points determined.


EFFECT OF VARYING THE
CONCENTRATION OF ACTIVATED SLUDGE
Graph #4
Oxygen Utilization Studies 2/24/38
Oum #1 Sl.A Sew.A S.S. 1,820
Oum #2 " " S.S. 2,980
Oum #3 " " S.S. 4,400
Oum #4 " " S.S. 5,500
Suspended Solids of Return Sludge A 11,600
B.O.D. of Sewage A (5 day) 172
Temperature of Run 20°
Composition of Mixtures
Water Sludge Sewage
Oum #1 1000 500 1700 ml.
Oum #2 700 800 1700 ml.
Oum #3 300 1200 1700 ml.
Oum #4 - 1500 1700 ml.
Oxygen Utilized in p.p.m. per Hour
Time in Hours


EFFECT OF VARYING THE
CONCENTRATION OF ACTIVATED SLUDGE
Graph #8
(% RETURN SLUDGE)
Oxygen Utilisation Studies 2/25/38
Oum #1 Sl.A Sew.A S.S. 3,750
Oum #2 " " S.S. 2,900
Oum #3 " " S.S. 2,100
Oum #4 " " S.S. 1,300
Suspended Solids of Return Sludge A 8,300
B.O.D. of Sewage A (5 day) 155
Temperature of Run 20C
45% Sludge 55% Sewage
35% Sludge 65% Sewage
25% Sludge 75% Sewage
15% Sludge 85% Sewage
Oxygen Utilised in p.p.m. per Hour
Time in Hours


EFFECT OF VARYING THE
CONCENTRATION OF ACTIVATED SLUDGE
Graph #9
Oxygen Utilisation Studies 3/3/38
Oum #1 Sl.A Sew.A S.S. 2,080
Oum #2 " " S.S. 3,400
Oum #3 " " S.S. 2,700
Oum #4 " " S.S. 4,100
Suspended Solids of Return Sludge A 8,680
B.O.D. of Sewage A (5 day) 139
Temperature of Run 10C
Composition of Mixtures
Water Sludge Sewage
Oum #1 750 750 1700 ml.
Oum #2v 500 1000 1700 ml.
Oum #3 250 1250 1700 ml.
Oum #4 - 1500 1700 ml.
Oxygen Utilised in p.p.m. per HOUR
Time in Hours

tration of sludge is raised and, apparently, is proportional to the suspended solids concentration of the mixture.

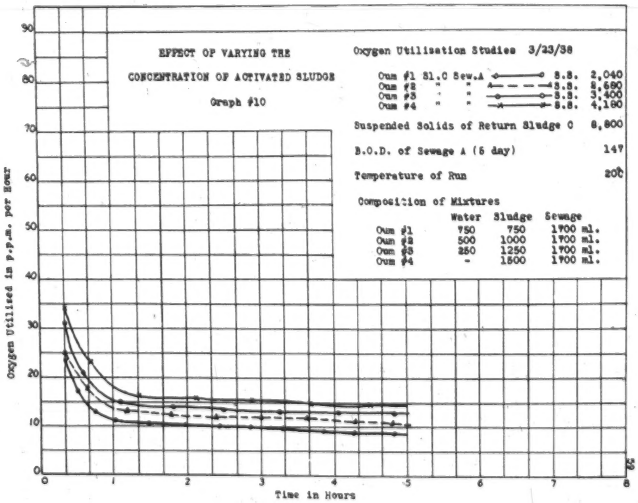
Fig. 3 is a summary of the sludge concentration studies made with Sludge A and shows that the relationships between the maximum oxygen utilization and suspended solids are linear functions at the various temperatures studied, but that the rate of oxygen utilization is not quite directly proportional to the concentration of suspended solids. The former is indicated by the fact that the experimental points determined on a given day all lie approximately on a straight line while the latter is indicated by the fact that the curves, as drawn, all intersect the vertical axis above zero. This seems rather unusual and indicates that some other factor is involved besides the activity of the added sludge; otherwise the curves when extended would pass through zero with part of them above and part below, due to experimental variations. Due to the fact that all of the experimental points seem to fit straight line curves, it does not seem possible that the anomaly is a function of extremely low suspended solids concentrations. Because of the fact that sewage itself is a biological medium teeming with life, it seems reasonable that this anomaly could be attributed to the sewage alone.

Such a sewage factor would increase the oxygen demand of all the various mixtures of a given run by a constant amount, since the same volume of sewage was taken for each sample. Thus, if each experimental point is corrected for this additional factor, the curves would all pass through the intersection of the vertical and horizontal axes and still remain as straight line curves. Evidence for the existence of an additional factor in the oxidation of sewage by activated sludge is also shown on Graphs 1 and 10 which are not plotted on Fig. 3. Inspection of Graph 1 shows that the maximum rate of oxygen utilization by the higher suspended solids concentration is not twice as great as with the lower solids concentration, although the solids are in the ratio of two to one. Graph 10 illustrates the same thing in probably a more emphatic manner.

Experimental work, as carried out in the laboratory, is often much different from the conditions involved in actual practice. There is, therefore, an important step between laboratory experimentation and plant practice. Realizing that the procedure used in these studies, of adding distilled water to make up a difference in volume when varying amounts of sludge were used, was impractical in plant operation, it was decided to make a run in which the difference in volume would be made up with sewage as in the case of actual plant practice. Results of this run are shown in Graph 5 and can be compared with Graph 4 which shows the results of a run made at the same temperature with distilled water added as a diluent. Comparison of Graphs 4 and 5 shows the effect of the additional food, supplied by the increased sewage volume, used in the experiments simulating actual plant conditions (Graph 5). The maximum rate of oxygen utilization is seen to be greatly extended in the cases of low sludge volumes with high sewage volumes. This is to be expected since it has been shown by Kessler and Nichols (8) that

the duration of the maximum oxygen utilization is related to the amount of food material in the sewage.

Another factor of interest, which is shown by the curves illustrating the simultaneous concentration studies, is that the oxygen utilization curves for the higher sludge concentrations break and drop to a low level before the break occurs in the case of the lower sludge concentrations. This low level of oxygen utilization reached by the higher sludge concentrations is usually below the oxygen requirements of the other sludge concentrations until the time when the break occurs in the latter curves; then the curves drop into their proper positions with respect to the suspended solids concentration. This indicates that, during a certain period of the oxidation process in actual plant prac-



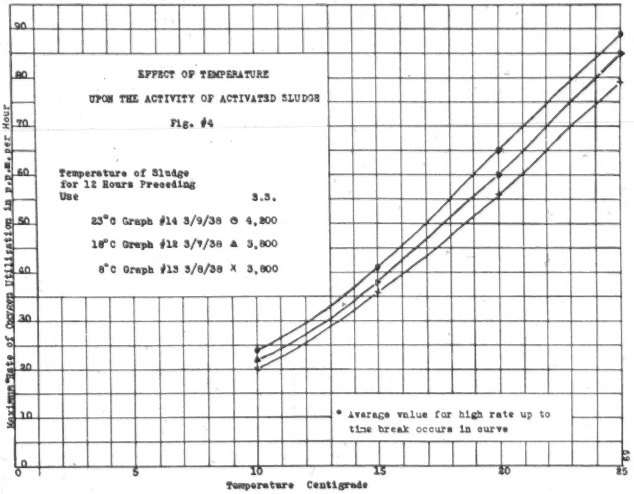
tice, less oxygen is required with high sludge concentrations than would be necessary if a lower amount of sludge were carried.

For example, Graph 1 shows that the mixture containing 2,680 p.p.m. of suspended solids requires less oxygen after 2½ hours have elapsed than the mixture containing only 1,340 p.p.m. of suspended solids. This condition exists for about 1½ hours and then the oxygen utilization by the lower solids mixture drops below that of the other mixture. Similar situations are shown in the other graphs except in Graph 10. With Sludge C the maximum rate of oxygen utilization did not persist long enough to be resolved into a definite curve during the extremely short critical period.

The discovery that mixtures with low solids concentrations may have a greater oxygen demand during a certain period of the oxidation

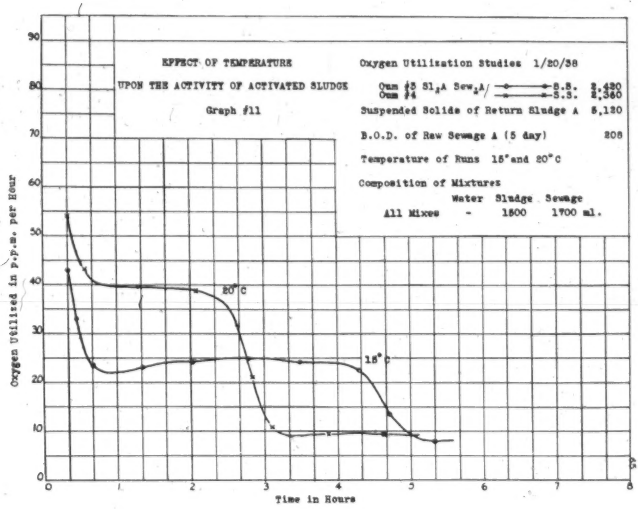
process than those with high solids concentrations is of a fundamental nature and must be taken into consideration if the principle of Tapered Aeration is to be properly applied in plant control when sludges of the character of Sludge A are involved.

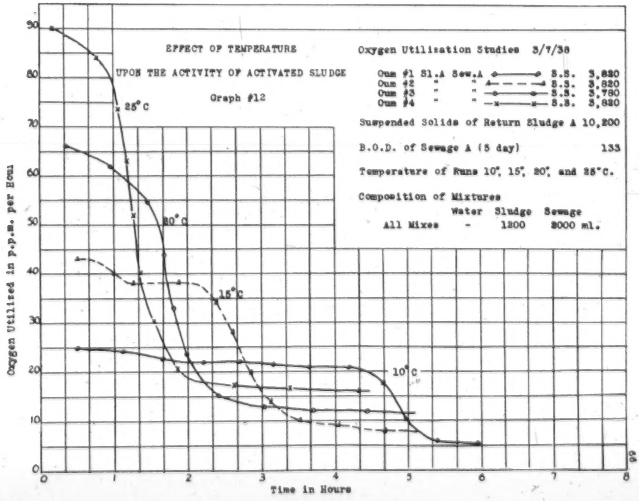
Simultaneous Temperature Studies (*Graphs 11 to 14 incl., also Fig. 4*).—The importance of the effect of temperature upon the rate of oxygen utilization is shown in a qualitative way in Fig. 3. In con-

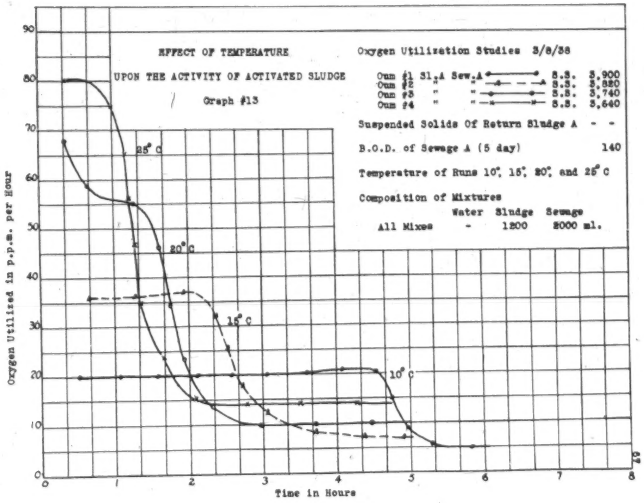


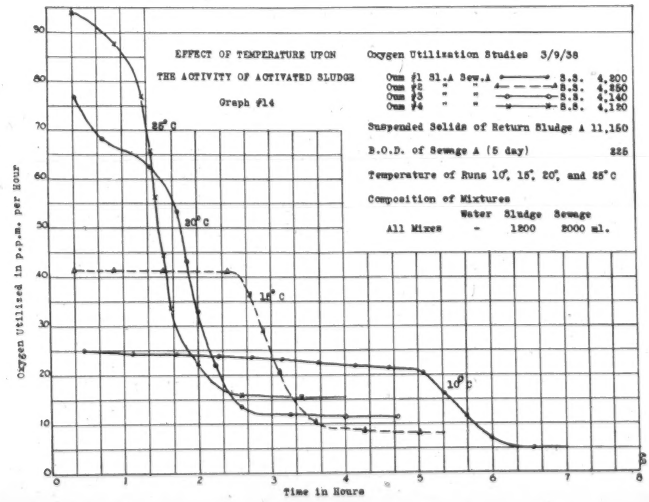
sidering this information, it must be remembered that the studies at the different temperatures were done on separate days and that the character of the sewage and the activity of the sludge was not necessarily the same on any two of the runs. In other words they were not simultaneous runs when considered from a temperature viewpoint.

The results of the simultaneous temperature studies are shown in Graphs 11 to 14 inclusive, and indicate the magnitude of the effect of temperature upon the rate of oxidation. At the higher temperatures, the rate of oxygen utilization greatly exceeds that at the lower temperatures. This results in the completion of the maximum rate of oxidation at the higher temperatures first and a drop to a low level of oxygen usage before the break in the curves occurs at the other temperatures. This is very well illustrated in Graph 11 which shows that the rate of oxygen usage by the mixture at 20° C. is much greater than at 15° C., and continues so until approximately 3 hours have elapsed; then the rate drops to a level below that at 15°. This condition lasts for about two hours; then the break in the 15° curve occurs and its rate drops below that at 20°. The situation is analogous to that created


EFFECT OF TEMPERATURE
UPON THE ACTIVITY OF ACTIVATED SLUDGE
Graph #11
Oxygen Utilization Studies 1/20/38
Oxygen Utilized in p.p.m. per Hour
Time in Hours
20°C
15°C


EFFECT OF TEMPERATURE
UPON THE ACTIVITY OF ACTIVATED SLUDGE
Graph #12
Oxygen Utilization Studies 3/7/38
Oxygen Utilized in p.p.m. per Hour
Time in Hours
25°C
20°C
15°C
10°C


EFFECT OF TEMPERATURE
UPON THE ACTIVITY OF ACTIVATED SLUDGE
Graph #13
Oxygen Utilisation Studies 3/8/38
Oxygen Utilised in p.p.m. per Hour
Time in Hours
25° C
20° C
15° C
10° C


EFFECT OF TEMPERATURE UPON
THE ACTIVITY OF ACTIVATED SLUDGE
Graph #14
Oxygen Utilisation Studies 3/9/38
Oxygen Utilised in p.p.m. per Hour
Time in Hours
25° C
20° C
15° C
10° C

by varying sludge concentrations at the same temperature, as discussed previously, and consideration of its effect is also necessary in the application of Tapered Aeration Methods in plant operation.

In making these temperature studies, an attempt was made to show whether or not the temperature at which the activated sludge was maintained for several hours prior to the time the run was started had any effect. The sludge used to obtain the results in Graphs 12, 13 and 14 was kept at 18, 8 and 23° C. respectively for 12 hours prior to making the runs.

An inspection of the graphs does not seem to indicate any detrimental effect caused by keeping the sludge at different temperatures for as long as twelve hours prior to its use. The change in activity with change in temperature seems to be immediate without any time lag being involved.

A correlation of the results shown on Graphs 12 to 14 inclusive is given in Fig. 4. This shows definitely that short-time storage at varying temperatures does not change the characteristics of the sludge with respect to activity at various temperatures since the curves do not cross at any place.

The character of the curves in Fig. 4 indicates that the change in activity with temperature change is not quite a linear function. The change in the slope of the curves is most pronounced between 10° and 15° C. and indicates that the activity of the sludge is affected least by temperature change at the lower temperatures. This is probably best shown by the following comparison, which is taken from the data shown in Fig. 4.

Maximum Activity	*Increase per 5° Interval*
10° = 22	10° — 15° = 15
15° = 37	15° — 20° = 23
20° = 60	20° — 25° = 25
25° = 85	

This shows that the increase in activity for each degree in temperature rise becomes greater at the higher temperatures. Still another way of considering the temperature relationships is to assume the activity at the highest temperature to be equal to 100 per cent and then rate the others on this basis. By doing this and using the values given above the following results are obtained:

Activity at 25° C. = 85 = 100%
Activity at 20° C. = 60 = 70.5%
Activity at 15° C. = 37 = 43.5%
Activity at 10° C. = 22 = 26.0%

The change in activity per ten degree rise in temperature corresponds very well with observations made on rate of growth of various organisms such as yeast cells where the growth may be trebled with a rise of 10° C. in temperature.

Discussion

Experience with activated sludges obtained from seven different municipalities has shown that the character of the oxygen utilization curves obtained when they are treated with sewage correspond to either the type given by Sludge A or the type given by Sludge C. The majority of them give curves corresponding to Sludge C. Thus it would seem that we have in Wisconsin at least two types of activated sludge with which to concern ourselves.

Oxidation of sewage by Sludge A shows two definite stages of oxidation. The first stage is characterized by a rate three to five times as rapid as the second and lasts for periods inversely proportional to the amount of sludge contained in the mixture. This is substantiated by the fact that for a given run, the areas under the curves or the amount of oxygen used up to the time of the transition, in most cases correspond to each other within a few per cent. Thus, if the amount of purification taking place can be interpreted in terms of oxygen utilized, it would seem, with sludges of this type, that the detention period required for treatment of the sewage would vary in inverse proportion to the amount of activated sludge (*i.e.* suspended solids) used in the aeration mixture. This conclusion corresponds to that advanced by Harris, Cockburn, and Anderson (9) but is contrary to that of Grant, Hurwitz, and Mohlman (1). A difference in the character of the sludges used may account for these divergent results.

Oxidation of sewage by Sludge C and other sludges of this type show rapid rates of oxidation in the beginning which drop rapidly to relatively low levels. Therefore, comparisons of the rate of oxidation by various concentrations of sludge can best be made at times when the rate of oxygen utilization has become more or less constant for all the mixtures. An inspection of the curves given by Sludge C indicates that the rate of oxygen usage is proportional to the amount of activated sludge present if consideration is given to the so-called "sewage factor" involved. The results on this sludge, however, are too meager from which to make a generalization.

The difference between the effects of temperature upon the rate of oxidation, as reported in this paper and the conclusions reached by Viehl (5), are in marked contrast. Although no attempt was made, in the work just reported, to separate the oxygen used into that used for nitrification and that used for oxidation of the organic matter, it is safe to assume that a good share of the oxygen used disappeared in the oxidation of carbon and hydrogen. And since the rate of the total oxidation corresponds quite well with the van't Hoff law, it seems that the oxidation of the organic matter probably follows the same law. Viehl's conclusions, in regard to the rates of the oxidation of organic matter, were based on B.O.D. removal principally. It has been recognized by several investigators that B.O.D. removal by activated sludge is influenced markedly by adsorption and other physical phenomena and is not synonymous with rate of oxidation.

The great change in activity, with the variations in temperature, as determined for Sludge A, is what would be expected on the basis of the close temperature control that has been found necessary to give comparable results in B.O.D. work. The fact that satisfactory operation of plants is accomplished under winter conditions at or even below the lowest temperature studied indicates that a compensatory factor may intervene during winter conditions. On the other hand, perhaps a knowledge of the temperature relationships will help solve some of our bulking troubles, which occur most frequently during the summer months, since the higher temperature may favor the growth of the filamentous organism *Sphaerotilus natans,* which is encountered so frequently in bulking sludge. For plants which encounter impaired purification during the winter, a consideration of the effects of temperature changes in conjunction with those of sludge concentration should prove of benefit.

Since only one sludge has been used to obtain the temperature relationships presented here, it should not be assumed that they apply quantitatively to all sludges. Further studies on several sludges under both winter and summer operating conditions are planned to determine whether the same relationships hold for all sludges under the extreme operating conditions. It is hoped that by obtaining this information it will become possible to translate results obtained in the laboratory at one temperature to actual conditions in the plant at any temperature.

Summary

1. Results of simultaneous sludge concentration investigations performed with activated sludge-sewage mixtures at each of the temperatures 10°, 15°, 20° and 25° C. have shown that at any of the temperatures the rate of oxygen utilization is the sum of two factors. One factor, usually rather small as compared to the total, is independent of the concentration of sludge used and has been attributed to the sewage. The magnitude of the second factor, or largest one, is directly proportional to the amount of activated sludge (*i.e.* suspended solids) in the mixture.

2. Activated sludges obtained from two Wisconsin municipalities were subjected to the sludge concentration studies and each sludge gave a different type oxidation curve. Results (unpublished) of oxygen utilization studies made with activated sludges obtained from seven Wisconsin cities have shown them to give oxidation curves which belong to either one or the other of these two types.

3. Simultaneous temperature studies made at 10°, 15°, 20° and 25° C. have shown the rate of oxygen utilization at 10°, 15°, and 20° C. to be 26, 43.5, and 70.5 per cent respectively of the rate of oxygen utilization at 25° C. Aeration of the sludge at 8°, 18°, and 23° C. for periods of 12 hours prior to the time the temperature studies were made had no effect on the temperature relationships.

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Plant Operation

A COMPARISON OF THE PERFORMANCE OF IMHOFF TANKS AGAINST PRIMARY SETTLING TANKS

By W. S. Mahlie

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In 1924, the City of Fort Worth put into operation four Imhoff Tanks. These tanks were of the double flow chamber, double sludge chamber type, rectangular in shape. The length was 96 ft. and the width of a single flow chamber was 16 ft. Each double unit or complete tank had a central gas vent 2 ft. 6 in. wide running the entire length of the tank, and two side gas vents each 2 ft. 9 in. wide running parallel to the middle gas vent, giving an area of 25 per cent of the flow surface area. The depth of the tank from the top to the flow line was 18 in., and from the flow line to the spring line of the sloping diaphragm baffles, 20 in. The depth from the spring line to the slot was 9 ft. 4 in. The total depth of the tank from the flow line to the bottom of the sludge chamber was 23 ft. 10 in. The sloping diaphragm walls were only 3 in. thick, formed by plastering concrete on a skeleton of metal lath. The total sludge capacity was 1.2 cu. ft. per capita.

From the beginning these tanks gave trouble with foaming. After eleven months operation the diaphragm walls of one of the tanks collapsed; the cause of this was never determined, although it was supposed that a sudden release of accumulated gas caused a "water hammer" which resulted in the breaking of the walls.

The plant was enlarged in 1929 when a fifth Imhoff tank was added and a pre-aeration tank was built. This pre-aeration tank was placed between the Imhoff tanks and trickling filters, so that the Imhoff tank effluent was aerated before going to the filters.

Immediately on starting this pre-aeration unit, serious odor difficulty was encountered, which was and still is exceptionally bad at certain times.

It should be mentioned that the plan of operation of the enlarged plant called for allowing some digestion to take place in the Imhoff tanks, and then to pump this partly digested sludge to three separate digestion tanks for final and complete digestion. Such a procedure resulted in continuous foaming. It was impossible to use the Imhoff tanks strictly as primary sedimentation tanks because the bottom construction was such that the sludge accumulations could not be removed completely. Thus there was always enough sludge to seed the incoming solids. In addition, the thin diaphragm walls had developed large cracks which allowed the gases from digestion to diffuse upward into the sewage passing through the settling compartment.

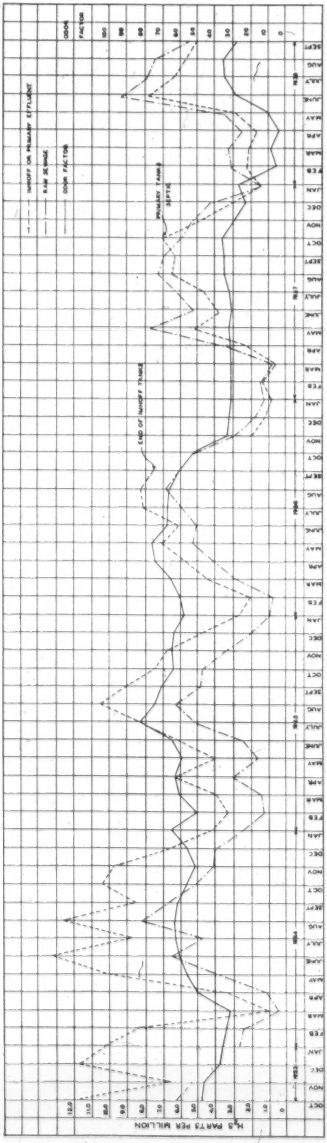

FIG. 1.—Fort Worth, Texas, sewage disposal plant. Comparison of H_2S in raw and settled sewage and odor intensity, Imhoff vs. Primary Tanks.

By referring to the accompanying graph it will be seen that the hydrogen sulfide content of the tank effluent was always higher than that of the influent, and one can easily imagine the embarassment of the plant operator trying to keep down odors when he had a hydrogen sulfide manufacturing unit in the plant. On an average for a three-year period these tanks produced 250 lb. of H_2S daily, an increase of 3.2 p.p.m. (In fact the actual production was somewhat greater than this, because the samples were taken after the sewage had flowed over a weir, where a small quantity was liberated by the splashing and aeration.)

Recommendations were made to remodel the Imhoff tanks very shortly afterward but the money was not forthcoming until 1936, when a P.W.A. grant was secured and the work proceeded.

Two Imhoff tanks were converted to straight-flow primary tanks, by knocking out the baffle walls, and filling the sludge compartment with 1:27 concrete. These rebuilt tanks are 95 ft. 6 in. long and 41 ft. wide,

COMPARISON IMHOFF TANK VS. PRIMARY TANK OPERATION—FORT WORTH, TEXAS

	Period A	Period B
Average Sewage Treated Daily, million gallons	9.674	11.572
Average Settling Time, hours	1.83	1.66
Suspended Solids—Influent average, p.p.m.	338	362
Suspended Solids—Effluent average, p.p.m.	128	180
Per cent Removed	61.8	51.7
Settleable Solids—Influent average, c.c./l.	6.59	7.12
Settleable Solids—Effluent average, c.c./l.	0.46	1.24
Per cent Removed	92.9	84.8
5 Day B.O.D.—Influent average, p.p.m.	374	422
5 Day B.O.D.—Effluent average, p.p.m.	244	300
Per cent Removed	34.9	30.0
Population Equivalent—Influent, daily	177,600	233,900
Population Equivalent—Effluent, daily	115,700	166,300
Population Equivalent Removed	61,900	67,600
Suspended Solids—Influent lb., daily	27,250	34,910
Suspended Solids—Effluent lb., daily	10,320	17,360
Suspended Solids Removed lb., daily	16,930	17,550
Total Solids in Sludge, per cent	3.62	4.77
Volatile Matter in Sludge, per cent	67.55	70.71
pH Value	6.4	6.1
Gallons Sludge Pumped, daily	87,000	83,000
Gallons Scum Pumped, daily	28,000	1,100
Man-hours Labor, daily	10.8	0.77
H_2S in Raw Sewage—Average, p.p.m.	4.1	4.7
H_2S in Imhoff Tank Effluent—Average, p.p.m.	7.3	
H_2S in Primary Tank Effluent—Average, p.p.m.		3.9
H_2S Received Daily, lb.	322	434
H_2S Produced Daily, lb.	250	
H_2S Removed Daily, lb.		80
H_2S Going to Aeration Tanks Daily, lb.	572	354
Odor Factor	60.4	28.9

Period A—Inhoff tank operation from October 1, 1933 to October 31, 1936.
Period B—Primary tank operation from Nov. 1, 1936 to September 30, 1938.

with an average depth of 13 ft. 5 in. They were equipped with three flights of sludge scrapers (also acting as skimmers), a cross flight at the end for drawing the solids to a sump, and a top cross flight to remove scum at the other end. The total volume of the two tanks is 105,720 cu. ft., while the volume of the settling compartments of the five Imhoff tanks was 105,160 cu. ft. Thus two primary tanks give the same detention time as the original Imhoff tanks. The converted tanks were placed in operation about November 1, 1936.

The following table shows the comparative results of operation for a three-year period of Imhoff tank operation against two years of primary tank operation.

The term "odor factor" should be explained. For more than six years an odor record of the various units at the plant has been kept. The observations are made twice daily, morning and evening. The odors are recorded as none, faint, distinct, and strong. Numerical values of 0–1–2 and 3 respectively are assigned to these classifications, and the results are calculated to percentage. For example, assume a month of 30 days; if a strong odor (the maximum value) is present on each day we would have a value of 90 points. The maximum possible value would also be 90, and $90/90 \times 100 = 100$ per cent. If a monthly summary showed 10 days of no odor, 5 days of faint odor, 10 days of distinct and 5 days of strong, the calculations would be: (10×0) plus (5×1) plus (10×2) plus (5×3) equals 40/90, or 44.4 per cent as the odor factor.

In comparing the performance of the two periods, consideration should be given to the increased quantity and strength of the raw sewage in Period B as compared to Period A.

SLUDGE DRYING AND INCINERATION *

By D. C. Reybold

The Dorr Company, Inc., Chicago

The subject of sludge disposal enters into the design of any sewage treatment plant. The selection of a particular type of sludge treatment depends not only on the first cost but also on the operation costs. In addition to the problem of economics, problems of area requirements, odor nuisances, power generation, ultimate disposal, and public opinion enter into the selection of the type of sludge treatment.

Development and research in the past 20 years have produced tremendous advancements in the treatment of sewage. Until recently, except for advancements in digestion and in power generation from digestion gas, very little progress has been made in new or improved methods of sludge disposal. Even in modern disposal practices the final digested sludge is 90 per cent water and contains some 40 per cent volatile matter, which must be taken into consideration in the ultimate disposal.

To the average layman the problem of sewage treatment is complex. He finds sewage contains an average of less than $\frac{1}{20}$ of one per cent of solids. Yet he sees as much area and equipment required for handling this minute volume of sludge as is required to handle the tremendous volume of liquid. He notices sludge removal mechanisms, sludge pumps, digestion tanks with large amounts of sludge storage, heating equipment and accesories, and huge areas of sludge beds. All of these are normally required in our modern sewage treatment plants. Furthermore, the layman is then told that, even with this array of tanks and devices, he still has the problem of disposing of a sludge bed product, which contains probably some 50 per cent water. He begins to believe that instead of calling the plant a sewage treatment project it should be renamed a sludge disposal plant.

In the last few years sanitary engineers, research chemists, operators, and equipment companies have been tackling the problem of sludge disposal as never before. We have observed advances in digestion practice by the use of multiple tanks in series, the use of power generation to defray operating expenses, the use of mechanical dewatering devices with elutriation, and the construction of glass-covered sludge beds for winter operation. At the same time devices for incineration of sludge for ultimate disposal have been developed.

It is not my purpose in this paper to go into the economics of the various methods of sludge disposal, or to analyze various types of incinerators, or to make operation comparisons.

It is my intention to describe the theory, history and development of the process of flash drying and incineration.

* Presented at the Eleventh Annual Meeting of the Central States Sewage Works Association, Neenah-Menasha, Wis., Oct. 13, 1938.

In burning wet materials it is more economical to separate the evaporation or drying cycle from the actual burning. This is true since the temperature of evaporation is considerably lower than that of combustion. An economically operated incinerator must first dry the material and then burn it in a subsequent operation.

Drying by artificial heat is limited by economics, as a rule, to sludge which contains less than five or six parts of water per part of dry solids. Materials which originally contain a larger ratio of water are treated by mechanical means to reduce the water to the required content. The cost of moisture removal per unit of moisture increases as the sludge becomes lower in moisture. Thus a clarifier will separate liquid from solids at a minute fraction of the cost entailed by direct heating methods. Drying, therefore, may involve a series of operations, the last of which is flash drying. The number of operations depends upon the initial moisture content. The preliminary mechanical dewatering operations may imply thickening, pressing, centrifuging, or filtration.

Atomized drying was first recognized in a patent issued in 1872 to R. Percy of New York. He patented a method of atomized drying of solids, semifluids, and fluids by means of hot air, the atomized material being dried while the particles floated in the air. This was followed by similar patents, most of which were based upon the spraying of a liquid or a slurry into a chamber, where it was mixed with a rapidly moving stream of hot air. The dried solids either collected at the bottom of the chamber or were swept out with the moisture-laden air into a cyclone separator. This method has been used in the drying of milk, fruit juices, rubber latex, dissolved and precipitated salts. All of these involved recovery of dissolved, colloidal or finely precipitated matter having no appreciable particle size.

Somewhat later, this principle of drying began to be applied to the dehydration of wet mineral and organic materials containing larger particles. A basic drying principle is to produce a maximum moist surface exposure. Thus some form of disintegrating or beating was added to the process in order to break up the particles and insure that the greatest possible surface be exposed to the hot air. In the present development of this process, which is called flash drying, the material is dispersed in a mill, beaten and mixed with a blast of preheated air, then swept into vortex separating chambers. The applications of this system have been in the preparation of powdered coal, sewage sludge, precipitated sulfur, bone meal, vegetable pulps, spent grain, and fertilizer products.

Flash drying is an efficient method of drying such materials. It insures the instantaneous removal of surplus moisture, and provides for handling the dried product in a dust-tight system in one continuous automatic operation, entirely distinct and separate from the burning portion of the process. To present a maximum wetted area to the hot drying gases, a portion of the material previously dried is returned and mixed with the wet sludge filter cake.

In addition to this fundamental requirement of having as large a wetted surface area as possible exposed to the hot gases, the following basic principles must be followed to obtain the best efficiency and greatest utilization of the available heat in the sludge.

1. The water vapor film surrounding a wet particle must be continuously swept away. In rapid drying processes, mechanical agitation must be used to insure a high relative velocity between the particles being dried and the drying medium.

2. The temperature of the drying gases should be as high as conditions will permit.

3. Moisture must be free to move readily from within the particle to the enveloping vapor film. The particles in the drying system should not be allowed to lump together and must be as fine as possible.

4. Incinerators should operate with a minimum amount of air over the theoretical requirements for completing combustion. Excess air serves only to reduce efficiency by lowering temperatures, increasing loses in exhaust gases and increasing power requirements for fans.

5. Incinerators should operate with a minimum carbon loss in ash to prevent valuable fuel loss. High carbon loss in ash occurs when material is too lumpy.

6. Incinerators should have a high enough temperature to secure prompt ignition, promote complete combustion and destroy odors.

7. The drying gases containing the water vapor and obnoxious odors should be returned to the highest temperature zone in the furnace to insure complete odor removal.

At first glance the system of flash drying and incineration appears quite complicated. In analyzing the process it is noted that when each portion of the system is followed through separately it becomes quite simple. The chart Fig. 1, which shows the unit operations, illustrates the entire process and each successive step. The following description of the various steps in the operation may be readily understood by referring to this chart.

Sludge Preparation.—The wet sludge filter-cake from the vacuum filter is delivered to a mixer by means of a belt conveyor. In the mixer it is blended with a portion of sludge which has been previously heat-dried. Mixing the wet sludge filter cake with the heat-dried sludge, in this manner, produces a flaky product of uniform consistency, having a much lower average moisture content than the incoming wet filter cake. In this flaky form it is readily carried through the drying stage by the high velocity of the hot gases.

Flash Drying.—Taken in sequence the drying steps are as follows: The blended sludge from the mixer is fed to the inlet of the flash dryer where it meets the hot gases from the incinerating furnace. In the flash dryer the sludge particles are dispersed throughout the gas stream to produce the maximum wetted surface contact with the hot gases. From the flash dryer, the gas-borne sludge particles pass to a cyclone separator where dried sludge is removed from the cooled moisture-laden gases. The circulation of gas and sludge through the drying

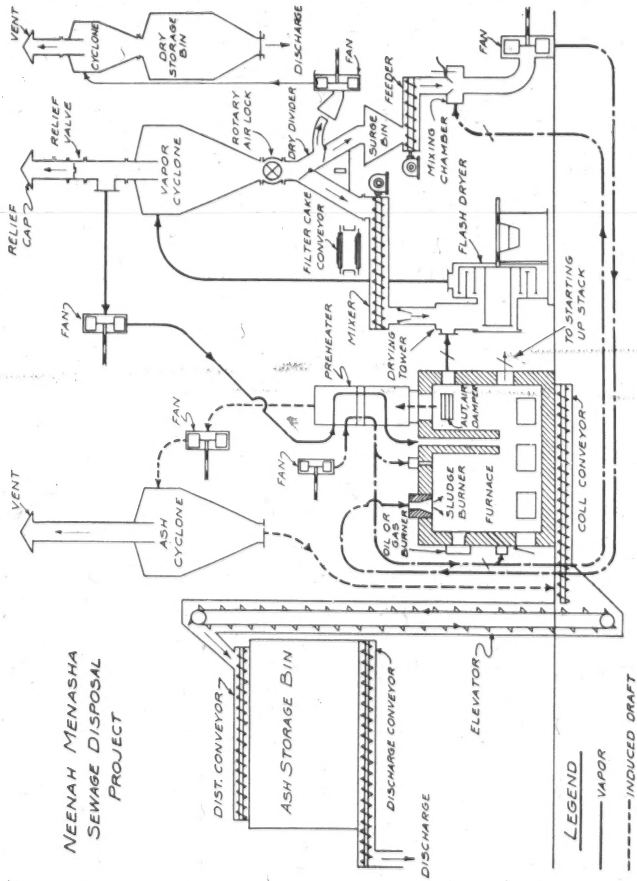
NEENAH MENASHA
SEWAGE DISPOSAL
PROJECT
FLOW SHEET
VENT
CYCLONE
DRY STORAGE BIN
DISCHARGE
FAN
FEEDER
SURGE BIN
MIXING CHAMBER
ROTARY AIR LOCK
DRY DIVIDER
RELIEF VALVE
RELIEF CAP
VAPOR CYCLONE
FILTER CAKE CONVEYOR
FLASH DRYER
PREHEATER
MIXER
DRYING TOWER
TO STARTING UP STACK
AUT. AIR DAMPER
SLUDGE BURNER
FURNACE
OIL OR GAS BURNER
COLL CONVEYOR
ASH CYCLONE
DIST. CONVEYOR
ASH STORAGE BIN
DISCHARGE CONVEYOR
ELEVATOR
LEGEND
VAPOR
INDUCED DRAFT
COMBUSTION
DRY SLUDGE

Fig. 1.

system is produced by a fan at the gas outlet of the cyclone separator. The elapsed time from the moment the blended sludge enters the flash dryer until it leaves the cyclone separator as dried sludge is a matter of only a few seconds. A part of the dried sludge leaving the cyclone separator is automatically returned to the mixer for blending with incoming wet filter cake and the rest is withdrawn as dried sludge or incinerated. The dried sludge will have from 5 to 8 per cent moisture.

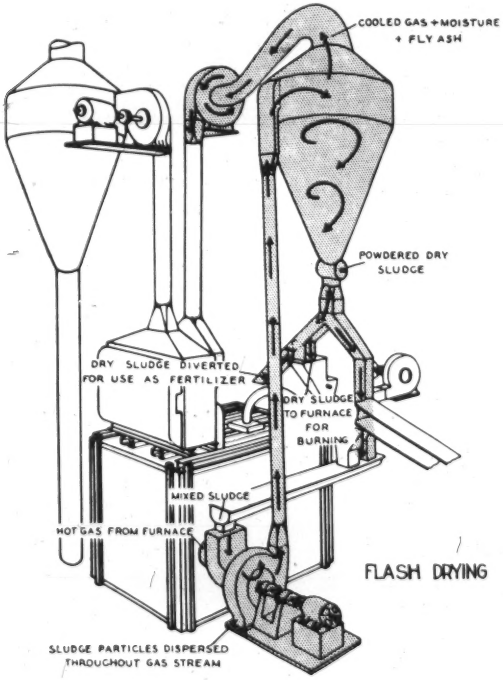
COOLED GAS + MOISTURE + FLY ASH
POWDERED DRY SLUDGE
DRY SLUDGE DIVERTED FOR USE AS FERTILIZER
DRY SLUDGE TO FURNACE FOR BURNING
MIXED SLUDGE
HOT GAS FROM FURNACE
FLASH DRYING
SLUDGE PARTICLES DISPERSED THROUGHOUT GAS STREAM

FIG. 2.

It may be used immediately or stored indefinitely without danger of decomposition or odor nuisance.

In this stage the temperature of the sludge will average about 160° F. with the temperature of the incoming gas about 1,300° F. and the outgoing temperature of moisture laden gas about 250° F. There is no overheating or igniting of the dry sludge particles and no loss of nitrogen content during this drying operation.

Sludge Incineration.—The dried sludge, except for a portion recirculated to the drying system and assuming it is not withdrawn for

fertilizer, is blown to the incinerator. In certain cases it may be possible to divert some sludge for fertilizer without the necessity of adding fuel. In most cases, where sludge is diverted, it is necessary to supply its heat equivalent from auxiliary fuel such as oil, or sludge digester gas.

The need for additional fuel depends on the available heat units in the sludge, which, in turn, depend on the volatile matter content.

The path of the sludge which is to be incinerated is illustrated on Fig. 1. The dried sludge, collected in a sludge bin, is uniformly fed into a duct which connects the pressure side of the sludge blower to the sludge burner in the combustion chamber of the furnace. The sludge blower, in addition to conveying the sludge to the furnace, also supplies the major portion of the air required for combustion.

Referring to the flow sheet and to the diagram Fig. 1, it can be seen that the cooled, moisture-laden gases from the cyclone separator are blown through a heat exchanger, where the temperature of the gases is raised before being introduced into the furnace. In the furnace, these gases are mixed with the products of combustion of the burning sludge and the temperature is raised to approximately that of the furnace gases. This temperature is 1,200 to 1,500° F., more than sufficient to destroy all odors. Any incinerator should be designed to have all gases and vapors from the drying cycle pass through a temperature of 1,300° F. before discharge from the furnace.

Following the deodorization step, a portion of the gas is conducted to the drying system. The rest of the gas leaves the furnace and is drawn through the hot side of the heat exchanger by an induced draft fan. There the gases give up their sensible heat to the cooler gases which are just entering the furnace from the cyclone separator. As a result, the gases passing out of the furnace on their way to the stack are cooled to a point at which they may be vented to the atmosphere without loss of valuable heat.

Dust Collection.—The final step is the removal of the dust or fly ash from these cooled gases before they pass up the stack and into the atmosphere. The cooled gases are blown by the induced draft fan into a fly-ash cyclone separator. The gases, along with the moisture from the drying operation, are then vented to the atmosphere.

Normally the greatest portion of the ash from the incineration of sludge is removed in the fly-ash separator and a much smaller portion from the ash pit of the furnace. All of the ash is in fine, powdered form, normally free from clinker and unburned organic matter and may be disposed of by any of the conventional methods of ash disposal. The actual method will depend upon local conditions.

Attempts have been made to dry and incinerate in one unit. This is not an economical way to handle wet material. Drying and incineration, being separate and distinct steps, should be separated in order to obtain the best efficiency. Deodorization and dust elimination are also distinct operations. Flash drying and incineration, by segregating these functions, has made it possible to treat each one separately and

effectively, each portion of the equipment being particularly adapted to that phase which it handles. A high thermal efficiency is possible and obtained in actual practice because of (*a*) direct contact drying, (*b*) complete control of the burning of dried sludge, (*c*) high efficiency of the heat exchangers, and (*d*) the design and arrangement of the system used.

This process can be so operated that it will produce stack gases free from obnoxious odors and dust. Provision is made for automatic con-

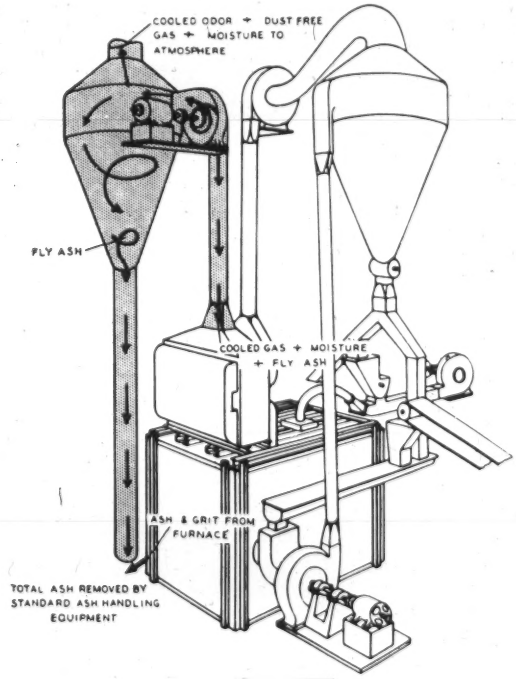
COOLED ODOR + DUST FREE GAS + MOISTURE TO ATMOSPHERE
FLY ASH
COOLED GAS + MOISTURE + FLY ASH
ASH & GRIT FROM FURNACE
TOTAL ASH REMOVED BY STANDARD ASH HANDLING EQUIPMENT

FIG. 3.—Dust Collector.

trols to take care of any condition that might arise because of stoppage of the feed.

No long periods are required for heating and cooling the furnace structure. The furnace may be started from cold within half an hour. During shut-down periods no fuel is required to maintain the equipment at an elevated temperature. There are no moving parts subjected to the intense heat of burning material.

The furnace has a suspended arch, independently supported from steel framework above the furnace, which is not affected by sudden

changes in temperature. All parts are readily accessible for renewal, with a minimum loss of time for shut-down and minimum cost for labor.

At the present time there are seventeen such sewage sludge drying and incineration units in operation or in course of erection in the United States.

They are listed as follows:

Location	No. Units	Tons Dry Solids/Day	Date Started
Sanitary District of Chicago, West Side Plant	1	20	Jan. '34 (Pilot plant dismantled)
Sanitary District of Chicago, Calumet Plant	3	70	Dec. '35
Hormel Packing Company, Austin, Minnesota	1		Oct. '37
Neenah-Menasha, Wisconsin	1	27	Nov. '37
Buffalo, New York	3	90	Aug. '38
Tenafly, New Jersey	1	4 (8 hrs.)	Oct. '38
Sanitary District of Chicago, Southwest Plant	8	400	Due '39

The history of sewage sludge flash drying and incineration is well illustrated by the installations in the various plants of The Sanitary District of Chicago. A full scale pilot plant was first built at the West Side Sewage Treatment Works to handle 20 tons of dry solids per day from filter cake containing 80 per cent moisture.

This plant was placed in operation early in 1934 and was operated for about two years. Its primary purpose was to determine important design factors for use in the construction of the Calumet plant.

The principal difficulties encountered at the West Side plant were the variations in moisture from the vacuum filter. Automatic controls have been developed and are now used to take care of similar moisture variations in filter cake.

The Calumet plant went into operation in April, 1936. This plant has a total incineration capacity of 70 tons of dry solids per day, from sludge containing 80 per cent water. The normal load is carried by two units, which leaves one spare unit at all times.

Recently some changes have been made in the conveying system at the Calumet plant to improve operating conditions. The operation of the flash drying and incinerating units has been satisfactory since the initial opening.

Construction is nearing completion at the Southwest plant. This installation, located near the West Side plant at Stickney, Illinois, has four incinerator units, each having a capacity of 120 tons of dry solids per day. These units are arranged with auxiliary fuel to generate through steam boilers the power for the Southwest plant.

The Neenah-Menasha, Wisconsin, sewage plant was built in 1937 and was designed by Greeley and Hansen. Considerable amounts of

paper wastes from the industries of the two municipalities influenced the design, since digestion and sludge-bed drying of the large amounts of paper solids required immense areas. Also there was no available information at that time on the possibility of digesting such large proportions of paper solids to sewage solids. Therefore, incineration was resorted to and this plant was designed to handle a maximum of 33,000 lb. of dry solids per day with a B.t.u. value of 4,500 per lb. of dry solids.

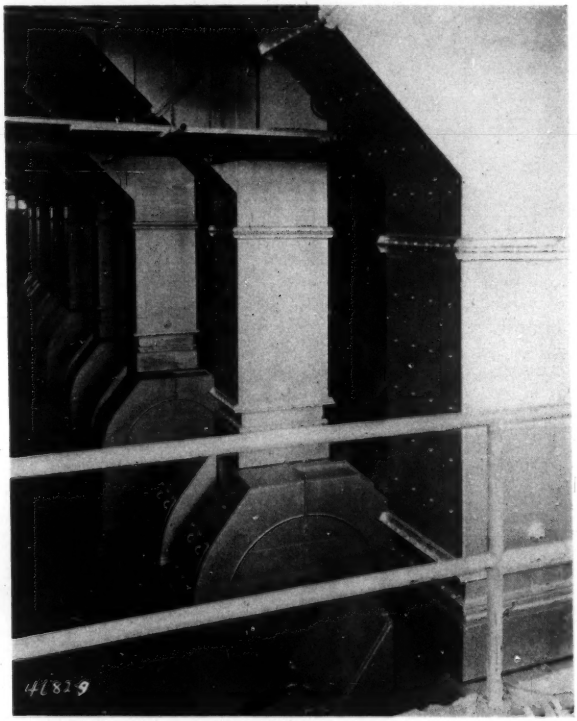

FIG. 4.—Flash dryers at Southwest Works of The Sanitary District of Chicago.

The flash drying and incinerating unit is designed to handle 1,500 lb. of dry solids per hour.

This installation went into operation in November, 1937. The only major change made has been to replace the lower elements in the preheater with a steel of higher alloy content to protect them against unduly rapid oxidation. Higher air temperatures leaving the preheater were encountered, since for proper operation 40 per cent excess air was required instead of the design amount of 20 per cent. This

situation was due to the unusual character of the sludge cake at Neenah-Menasha. The sludge contains such a high percentage of cellulose fiber and inorganic filler that an intensely hot flame is produced.

The Buffalo, New York, plant was designed by Greeley and Hansen for 90 tons per day of dry solids. This flash drying and incinerating system is to handle either vacuum filtered digested or raw sludge. This

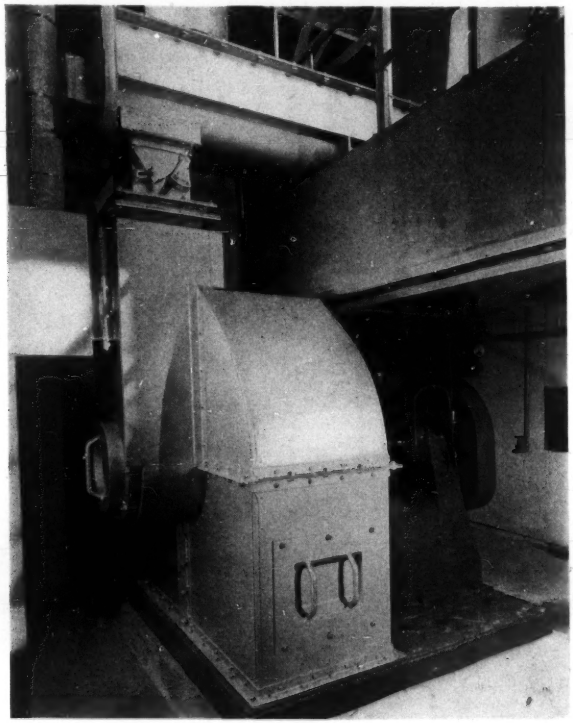

FIG. 5.—Flash dryer at Neenah-Menasha.

plant uses the rotary or regenerative type of heat exchanger, separate from the furnace.

The Hormel Company of Austin, Minnesota, installed a flash drying and incinerating system to handle the packinghouse wastes. This unit went into operation in 1937 and in addition to flash drying the wastes for fertilizer also dries some of the packinghouse by-products.

The City of Tenafly, New Jersey, uses drying in conjunction with an outside source of heat from a garbage incinerator. This plant consists

of a standard flash drying system with the heat for drying furnished by the burning of garbage and rubbish in a separate incinerator. An auxiliary oil-burning air heater has been supplied for operation during incinerator charging and for operation apart from the incinerator. The dried sludge may also be burned, if it is desired to dispose of it in that way instead of using it as fertilizer.

Advantages.—The individual units comprising flash drying and incineration systems are of standard design, but owing to the variations in sludge moisture, heat value of sludge, area available for plant, and other conditions, no attempt can be made to standardize on the system

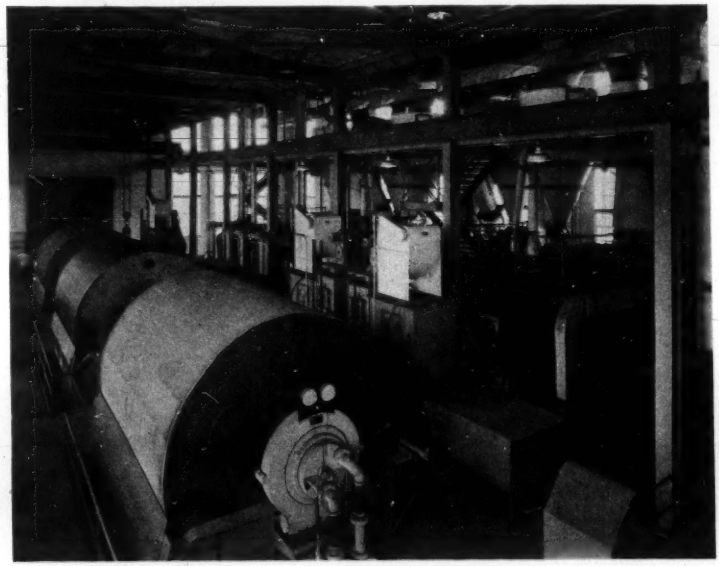

FIG. 6.—Vacuum filters and flash dryers at the Buffalo Plant.

as a whole. Each project is designed to take advantage of all factors, and although the arrangement may be different the underlying principles of drying and combustion are the same in all cases. There are many possible combinations for utilizing this flash drying and incinerating process. Some of these are as follows:

1. Complete drying and incineration.
2. Drying system operated in conjunction with an outside source of heat such as a garbage incinerator.
3. Drying system for producing fertilizer using digester gas for the source of heat.

4. Drying and incineration in combination with steam boilers for producing power.
5. Drying and incineration of filtered sludge combined with ground garbage.

Looking at sewage disposal from the broad standpoint of conservation, it would seem that the use of sewage sludge, particularly in the dried form, as a fertilizer is destined to play a more prominent part in the future. Certain European and Asiatic agrarian peoples have used raw sewage as a fertilizer in growing crops for centuries, but in the United States there has been a very strong prejudice against the use of sewage in any form for fertilizing garden crops.

It is very difficult to evaluate the market for heat dried sludge as no complete survey has ever been made of the disposal of sludge in the United States. The nearest approach to such a survey was one made in in 1937 by the United States Public Health Service, which reported a total population of 37,200,000 tributary to sewage treatment plants. The total number of plants in incorporated places was estimated to be 3,700, of which 2,000 had only primary treatment.

The quantity of suspended matter in the sewage from this population is approximately 1,631,400 tons annually which after digestion would yield 571,000 tons of dry sludge containing 11,420 tons of nitrogen on a 2 per cent basis.

An estimate made in 1936 by the Division of Fertilizer Investigations, Bureau of Chemistry and Soils of the United States Department of Agriculture, presented the following figures on the *Tons of Sludge Used as Fertilizer in the United States:*

	Tons	Est. % H_2O	Dry Wt. Tons
Heat-dried Activated	52,000	7	48,000
Air-dried Activated	10,000	50	5,000
Other Sludge	400,000	50	200,000
Total	462,000		253,000

Based on the two above estimates, it would appear that there might be still available 523,000 tons (571,000 — 48,000 = 523,000) of dry sewage solids for the production of heat-dried sludge in sewage treatment plants which are already established. This calculation does not take into account the many other cities and towns where sewage treatment plants are bound to be installed during the next few years. It therefore appears that the field for sludge drying and incineration has barely been scratched. The next step is to study the existing and projected sewage disposal plants for the purpose of selecting those where sludge drying and incineration is desirable and economically feasible. In practically all of the some 13 plants where heat drying of sludge is now practiced, the product is sold at prices ranging from $10 to $30 per ton.

The revenue from these sales naturally reduces the cost of operation of these plants.

It has already been shown that the flash-drying system is extremely adaptable to a wide variety of operating conditions. It is also flexible in the control of its production of a saleable product. In the growing season when the demand for fertilizer and soil conditioner is high, just enough sludge need be burned to furnish the heat needed to dry the remainder. If the demand becomes greater than the normal production rate, and the dried sludge can be sold at a good price, the output can be increased by burning a cheap fuel instead of sludge.

Then in the winter when there is little call for fertilizer, as much as desired or all of the sludge may be incinerated, thereby avoiding the building up of an embarrassing carry-over supply. There is not much that can be done about changing the quality of the dried sludge from a fertilizer standpoint except to mix in phosphate, potash, or other ingredients, to produce a properly balanced mixed fertilizer. This has been done in several instances to satisfy a local demand.

STORM WATER SEWER DESIGN *

By W. B. Redfern

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The subject of storm water sewer design is so comprehensive that one can deal only with certain phases of it within the limits of this paper. In designing storm sewers, the rational method is mostly used, and within limits this method provides a logical procedure for calculating sewer capacities. The design of combined sewers or of storm water sewers is identical, so far as capacity is concerned, for the reason that the sanitary flow may average less than one per cent of the storm flow. This is less than the accuracy possible for storm water sewer design. For a district having a large industrial flow compared to the sanitary sewage, this might not be so, but it would be a special case not coming within the general rule.

The general formula for the rational method is $Q = C\ i\ A$, in which Q represents cubic feet per second; C the run-off percentage; i the intensity of rainfall in inches per hour, and A the area of the district concentrating. By taking levels and preparing a contour plan of the area to be sewered, A can be determined, and is, in fact, the only factor in the formula that can be definitely determined. C, the run-off factor, varies in value from zero to unity, and is usually shown as a percentage. It is sometimes called "coefficient of run-off," or "coefficient of imperviousness," or "coefficient of impermeability"; "run-off percentage" is a concise expression. For a piece of ground completely paved or covered with a hard impervious surface, the run-off percentage might approach 100 per cent of the rainfall, especially after a storm has been in duration for some time when all the small holes or depressions would become filled with water and absorption would be zero. And C might be practically zero for rain falling on sandy soil for a short period of time, or, for a low intensity rainfall over a longer period. If the sandy soil absorbed all the rainfall, there would be no run-off. Between these limits of zero and unity or from 0 to 100 per cent of the precipitation, there are many intermediate percentages of run-off that might be selected according to the circumstances and conditions. For a well built-up downtown area, completely paved, roofed and sidewalked, the run-off percentage of precipitation might be as high as 70 per cent at the beginning of a storm, increasing to even 95 per cent as the storm continues, and all the little holes and pockets become filled with water and the demands of absorption have been fulfilled. For a high-class, residential district, the percentage might be 50 per cent, going as high as 60 to 65 per cent for an apartment house residential area. For a district having macadam roads and not many houses, the percentage

* Presented at the Meeting of the Canadian Institute on Sewage and Sanitation, Oct 20, 1938.

might be 25, and for park lands and undeveloped districts 15 to 20; for open flat country with sandy soil and high absorption, 10 per cent.

In Canada, special consideration should be given to the run-off from frozen ground in the spring of the year from undeveloped or partially developed territory. A rainfall on frozen ground with melting snow will result in a high run-off percentage.

There is opportunity here for the engineer to use his experience and judgment in selecting the run-off percentages. Not only should the character of the district be considered as it is to-day, but also as it might become within the economic period of design of the sewers to be constructed. In most cases, provision should be made for a greater percentage of run-off in the future as more houses, pavements, and sidewalks are constructed, or as the percentage of impervious area is increased. The amount of impervious area is largely the deciding factor in selecting the run-off percentage. The determination of a percentage for C in the formula is therefore a very important item, and should be decided upon only after a careful study of the factors entering into the problem.

The next and perhaps the most important factor in the formula to be considered is i—the rate of rainfall or intensity in inches per hour. Considering the precipitation in any district, there are comparatively few storms that reach high rates of precipitation. An all-day drizzle, or a 1-inch rainfall over a period of six hours, or a 2½-inch rainfall in twenty hours (as was recently the case in Toronto), should not in any way tax a storm-water sewerage system, but a short thunderstorm of high intensity might surcharge the system and cause a good deal of flooding of cellars and streets. In computations dealing with intensities, it is a fortunate circumstance that precipitation at the rate of 1-inch per hour equals 1 cu. ft. per second per acre on the basis of 100 per cent run-off, so that in plotting rainfall curves, inches of rainfall per hour have the same value as cu. ft. per second per acre.

In studying the records of rainfall, the data from automatic rain gauges are essential for the proper design of storm water sewers. These data furnish the basis of design for rates or intensities, which are the fundamental factors. The total rainfall in a year does not mean a thing so far as the design of storm sewers is concerned. The high intensity storms are the controlling features. In studying rates of precipitation, if they are available from an automatic rain gauge over, say, a period of 30 years, a one-year storm would be classified as a storm that was equalled or exceeded thirty times in thirty years; a two-year storm, fifteen times in thirty years; a five-year storm, six times in thirty years; a ten-year storm, three times in thirty years; a fifteen-year storm, twice in thirty years; and a thirty-year storm, the highest intensity storm in the thirty-year period.

In the period, there may be one or two phenomenal storms of extraordinary intensity that may not be equalled or exceeded in the next thirty years. The longer the record, therefore, the more accurate are the classifications for the different frequency storms.

There are great differences in intensities in different parts of the country. From a study of the U. S. meteorological reports, New York, for instance, experiences much higher intensities than Toronto and Detroit, though only 225 miles west of Toronto, in the past thirty years has had higher intensities than Toronto. It would seem, therefore, that no district can be taken as representative over a wide area. But, failing information from gauges in a municipality to be sewered, the best thing that can be done is to be guided by information from the nearest point where data are available, or from experience in other localities.

Through the courtesy of the Works Department of the City of Toronto, I have had the opportunity of studying data relating to high intensity storms in the Toronto area, and, from these data, have plotted rainfall curves for various frequencies, as shown in Fig. 1.

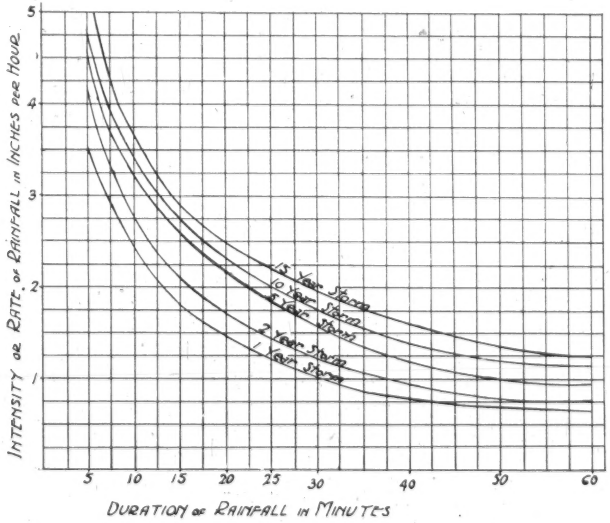

FIG. 1.—Rainfall curves for Toronto district showing intensity, duration and frequency.

These charts refer to records of the automatic rain gauge at the Morley Avenue Disposal Plant, which has been in operation for a longer period than the other gauges. On account of the configuration of the land and the general direction of the travel of storms, this station is probably the least exposed to heavy precipitation. One would have more confidence in these curves if they covered a period of 50 instead of 20 years, but they are at least approximately correct for the period for which information is available. It will be observed that the ten-year frequency curve shows intensities nearly 60 per cent higher than the one-

year frequency curve, and the fifteen-year curve 50 per cent higher than the two-year curve.

To translate the meaning of these curves relatively into the approximate cost of storm sewers, I have made certain assumptions and computed the cost of storm sewers using the different rainfall frequency curves. It would be possible to develop formulae to represent the value of points on the curves fairly accurately, but this is not necessary as the intensities can be taken from the points on the curves for the different times of concentration. The time of concentration includes the inlet time, and the time of travel through the sewers. In a general way, the intensities vary inversely with the square root of the time; that is, for a 16-minute time of duration, the intensity is approximately twice the intensity of a 64-minute period; or for a 4-minute period, four times the intensity of a 64-minute interval.

The following tables are based on three areas of 20 acres, 100 acres and 500 acres, respectively, each area concentrating to a trunk sewer to be constructed 1,000 ft. long to carry away the storm water from the different areas. The time of concentration for the area of 20 acres is assumed to be 15 minutes; for the area of 100 acres, 20 minutes; and for the area of 500 acres, 50 minutes. Different values of C are assumed for different kinds of municipal developments, that is, for well built-up business areas, residential areas, and sparsely settled districts with park lands, etc., the values of C are assumed to be 0.80, 0.40, and 0.20. Then various rates of rainfall are taken from the rainfall curves, as shown in Fig. 1, for 1, 2, 5, 10 and 15-year frequencies. From these the Q for each calculation has been derived, and the size of sewer required in each case computed by Kutter's formula, assuming $N = 0.13$, and all sewers assumed on a grade of 0.5 per cent. From the size of sewer, the average cost per 1,000 ft. of sewer installed has been calculated and set forth in the table on a comparative basis. No allowance is made for difficult types of excavation or for deep cuts, but the table is based on the assumption of average work for installing storm sewers, and is for comparative purposes only.

From a study of the tables, it will be seen that there is a considerable difference in the cost, depending upon the rainfall frequency, whether for a one-year, five-year, ten-year or fifteen-year storm. The question then arises, for what frequency should an engineer design a storm sewer? It would manifestly be prohibitive financially to construct storm sewers to carry away storm water of phenomenal storms of long frequency. Fortunately, very high intensity storms do not cover a wide area. A storm in Toronto on July 11, 1937, registered very high intensities at the Symes Road station, as follows: for 5 min. at the rate of 6.72 in. per hour; 10 min. 5.46 in., 15 min. 4.56 in., 20 min. 3.57 in., 40 min. 1.80 in., whereas at the Morley Avenue station, seven miles away, these rates were only 1.56 in., 1.50 in., 1.24 in., 1.23 in., and 0.69 in. respectively, for the same periods of time.

It would seem to the writer that intensities on the basis of at least the 10-year curve would be advisable for laterals and short trunk sewers

TABLE I

Assume area of 20 acres. Time of concentration including inlet time and time of flow in sewers is assumed to be 15 minutes. C, run-off percentage (coefficient of imperviousness), has different values for different assumed developments. Grade of sewers in all cases assumed to be 0.50 per cent. $Q = C\,i\,A$. i varies for different rainfall frequency curves.

(*a*) For sparsely developed land and park property, gravel roads, etc., C is assumed to be 0.20.

Frequency	$C\,i\,A$	C.f.s.	Diam. of Pipe	Cost Installed per 1000 Ft.
			Inches	
1-yr. storm	.20×1.80×20	7.2	20	$2,500
2-yr. storm	.20×2.10×20	8.4	20	2,500
5-yr. storm	.20×2.60×20	10.4	22	2,750
10-yr. storm	.20×2.75×20	11.0	24	3,500
15-yr. storm	.20×2.90×20	11.6	24	3,500

(*b*) For average residential districts with pavements, houses on most of the streets, paved driveways, roof drainage, etc., C is assumed to be 0.40.

Frequency	$C\,i\,A$	C.f.s.	Diam. of Pipe	Cost Installed per 1000 Ft.
			Inches	
1-yr. storm	.40×1.80×20	14.4	24	$3,500
2-yr. storm	.40×2.10×20	16.8	24	3,500
5-yr. storm	.40×2.60×20	20.8	27	5,000
10-yr. storm	.40×2.75×20	22.0	27	5,000
15-yr. storm	.40×2.90×20	23.2	27	5,000

(*c*) For built-up business districts, nearly all impervious surface, C is assumed to be 0.80.

Frequency	$C\,i\,A$	C.f.s.	Diam. of Pipe	Cost Installed per 1000 Ft.
			Inches	
1-yr. storm	.80×1.80×20	28.8	30	$5,500
2-yr. storm	.80×2.10×20	33.6	33	6,000
5-yr. storm	.80×2.60×20	41.6	36	6,750
10-yr. storm	.80×2.75×20	44.0	36	6,750
15-yr. storm	.80×2.90×20	46.4	36	6,750

In the above table, the diameter of the sewer varies from 20 in. to 36 in., and the cost per 1,000 ft. installed from $2,500 to $6,750 for different values of C and i.

where it would be costly to enlarge or build relief sewers in the future, but for long trunk sewers, a lesser frequency curve might be used where in 20 or 30 years a relief sewer might be constructed to advantage after the district sewered would approach the assumed point of development as provided in the original design. Some municipalities design storm sewers on the basis of a 10-year frequency curve, and there would seem to be good reasons for this procedure.

TABLE II

Assume area of 100 acres. Time of concentration is assumed to be 20 minutes.
(*a*) For sparsely developed land and park property, $C = 0.20$.

Frequency	$C\,i\,A$	C.f.s.	Diam. of Pipe	Cost Installed per 1000 Ft.
			Inches	
1-yr. storm	.20×1.45×100	29	30	$ 5,500
2-yr. storm	.20×1.70×100	34	33	6,000
5-yr. storm	.20×2.15×100	43	36	6,750
10-yr. storm	.20×2.30×100	46	36	6,750
15-yr. storm	.20×2.50×100	50	36	6,750

(*b*) For average residential district, $C = 0.40$

Frequency	$C\,i\,A$	C.f.s.	Diam. of Pipe	Cost Installed per 1000 Ft.
			Inches	
1-yr. storm	.40×1.45×100	58	39	$ 7,500
2-yr. storm	.40×1.70×100	68	42	8,250
5-yr. storm	.40×2.15×100	86	45	9,000
10-yr. storm	.40×2.30×100	92	48	10,000
15-yr. storm	.40×2.50×100	100	48	10,000

(*c*) For built-up business district, $C = 0.80$.

Frequency	$C\,i\,A$	C.f.s.	Diam. of Pipe	Cost Installed per 1000 Ft.
			Inches	
1-yr. storm	.80×1.45×100	116	54	$12,000
2-yr. storm	.80×1.70×100	136	54	12,000
5-yr. storm	.80×2.15×100	172	60	15,000
10-yr. storm	.80×2.30×100	184	60	15,000
15-yr. storm	.80×2.50×100	200	60	15,000

In the above table, the diameter of the sewer to drain the 100 acres varies from 30 in. to 60 in. and the cost for 1,000 ft. installed from $5,500 to $15,000, depending upon different values for C and i.

As to the capacity of storm sewers for which engineers should design, I refer to excerpts from some court cases that throw light on the responsibility of the municipality.

Some Excerpts from Legal Decisions on Size of Storm Sewers

Garfield vs. City of Toronto, 1895.—Where a sewer, built and maintained by a municipal corporation, is free from structural defect and is of sufficient capacity to answer all ordinary needs, the Corporation is not liable for damage caused, as a result of an extraordinary rainfall, by water backing into the cellar of a person compelled by by-law to use the sewer for drainage purposes.

TABLE III

Assume area of 500 acres. Time of concentration is assumed to be 50 minutes.

(*a*) For sparsely developed land and park property, $C = 0.20$.

Frequency	$C\,i\,A$	C.f.s.	Diam. of Pipe	Cost Installed per 1000 Ft.
			Inches	
1-yr. storm	.20×0.70×500	70	42	$ 8,250
2-yr. storm	.20×0.80×500	80	42	8,250
5-yr. storm	.20×1.00×500	100	48	10,000
10-yr. storm	.20×1.20×500	120	48	10,000
15-yr. storm	.20×1.35×500	135	54	12,000

(*b*) For average residential district, $C = 0.40$.

Frequency	$C\,i\,A$	C.f.s.	Diam. of Pipe	Cost Installed per 1000 Ft.
			Inches	
1-yr. storm	.40×0.70×500	140	54	$12,000
2-yr. storm	.40×0.80×500	160	60	15,000
5-yr. storm	.40×1.00×500	200	60	15,000
10-yr. storm	.40×1.20×500	240	66	18,000
15-yr. storm	.40×1.35×500	270	66	18,000

(*c*) For built-up business district, $C = 0.80$.

Frequency	$C\,i\,A$	C.f.s.	Diam. of Pipe	Cost Installed per 1000 Ft.
			Inches	
1-yr. storm	.80×0.70×500	280	72	$22,000
2-yr. storm	.80×0.80×500	320	72	22,000
5-yr. storm	.80×1.00×500	400	84	26,000
10-yr. storm	.80×1.20×500	480	84	26,000
15-yr. storm	.80×1.35×500	540	96	32,000

In the above table, the diameter of the sewer to drain the 500 acres varies from 42 in. to 96 in., and the cost per 1,000 ft. installed from $8,250 to $32,000, depending upon different values of C and i.

An extraordinary rain-fall may properly be treated as an act of God, in the technical meaning of that term, though it is not of unprecedented severity, if there is nothing in previous experience to point to a probability of recurrence.

It was shown that the storm in question had been a very violent one, nearly 1½ inches of rain having fallen in 25 minutes.

The rain-storm which caused the sewer to be overcharged with water was so extraordinary and unusual that the defendants could not be expected to anticipate it, and that it comes within the class of occurrence described as *actus Dei*.

J. A. Faulkner vs. City of Ottawa, 1908.—Faulkner brought action against the City of Ottawa claiming damages for the flooding of his premises by water backed up from the sewer with which his drain pipe was connected.

The Supreme Court held, with two members dissenting, that according to the evidence the sewer was capable of carrying off a fall of 1½ in. of water per hour, which was considered as meeting the requirements of good engineering, and was the standard adopted by all the cities of Canada and the Northern States; the city, therefore, was not liable.

The Court held, also, that a fall of rain at the rate of 3-in. per hour for 9 minutes was one which could not reasonably be expected and for which the city was not obliged to provide.

City of Montreal vs. Watt and Scott, Ltd., on appeal from the Supreme Court of Canada to the Privy Council, 1922.—A municipal sewer is a thing under the control of the municipality. Consequently, a municipality in the Province of Quebec is liable under Art. 1054 of the Civil Code for damage caused by an overflow of its sewer, if it fails to establish that it was unable (that is, unable by reasonable means) to prevent the overflow. The duty of the municipality is to construct its sewers so as to be capable of resisting all the violence of weather which may be expected, though perhaps rarely, to occur. It is therefore not exculpated under Art. 1054 by the fact that the overflow was caused by an exceptional storm, not amounting to a *cas fortuit* or *force majeure.*

Where the damage is partly due to the plaintiff's own negligence, the Court, according to the jurisprudence of Lower Canada, can reduce proportionately the damages payable by the defendant municipality.

The appellants, the City of Montreal, alleged that the rain-fall causing the overflow was of a kind so extraordinary as to constitute *force majeure,* but they were not successful in presenting this argument.

The judgment of the Supreme Court was affirmed.

The City of Kitchener vs. The Robe & Clothing Company, and The Standard Paving Co., 1925.—While the storm no doubt was unusually severe, the evidence in our opinion falls short of establishing that the rain-fall was so torrential and unprecented that it can be said to have amoounted to *actus dei* or *force majeure.*

The evidence of a witness, who had an instrument for use in measuring rain-falls, tells us it lasted for 1½ hours and the total fall was a trifle over 2 inches which, if we apply common knowledge, is not so great as pretended.

CHEMICAL TREATMENT AT WAUKEGAN, ILLINOIS *

By H. Gladys Swope

Chemist, North Shore Sanitary District, Waukegan, Illinois

The Waukegan sewage treatment plant is a chemical precipitation-Imhoff tank plant, designed for a flow of ten million gallons per day. The sewage flows by gravity to the plant, passes through a coarse bar rack (5½ in. openings), through a comminutor and is then pumped to the grit chambers. After passage through the grit chambers, the sewage may reach the Imhoff tanks through one of three routes; first, directly; or it may go through the flocculators; or else through a preaeration channel for grease removal, a grease tank, through the chemical building to the flocculators, then to the Imhoff tanks, chlorination chamber, contact tank and finally to Lake Michigan (Fig. 1). During the summer chemicals are added and the final effluent is chlorinated.

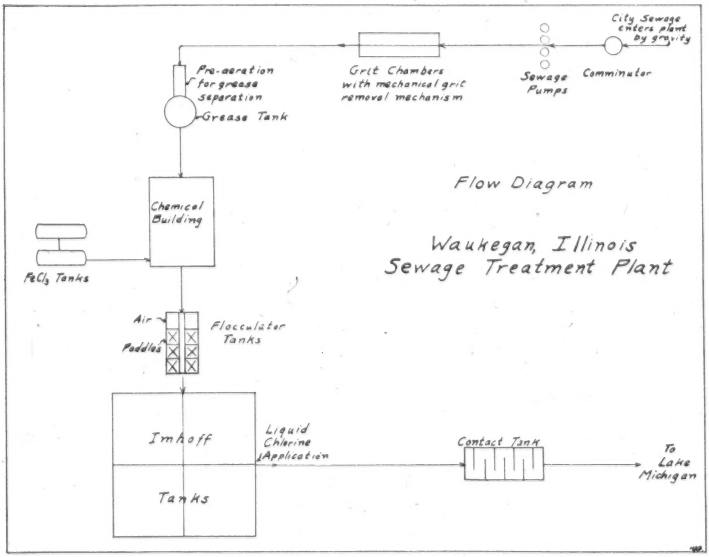

Fig. 1.

There are two flocculators (Fig. 2) each divided into four sections by means of baffles. In the first section air produces the rapid mixing of the chemicals with the sewage. There is a paddle in each of the

* Presented at the Eleventh Annual Meeting of the Central States Sewage Works Association, Neenah-Menasha, Wisconsin, October 13–14, 1938.

remaining divisions of the flocculators, placed at 30 degrees to a vertical shaft and 4 in. above the bottom of the flocculator. The paddle revolves at a rate of three revolutions per minute.

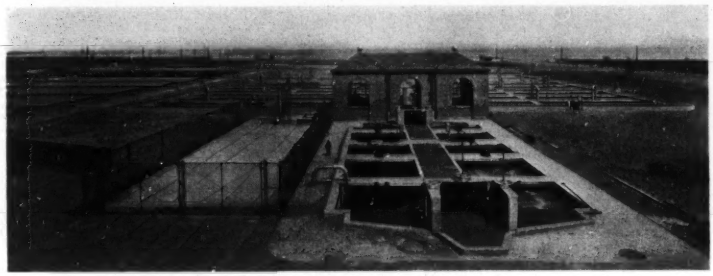

FIG. 2.—View looking east from main building, showing flocculators in foreground, then chlorine house, and Imhoff tanks in background.

The plant was put into operation on January 13, 1937, and chemical treatment was begun in July, 1937, and continued through October.

During the first season, ferric chloride and lime, and ferric chloride alone were used as coagulants. The ferric chloride used was the 45 per cent solution which was purchased in tank car lots and stored in rubber lined tanks at our plant. The lime used was hydrated lime, $Ca(OH)_2$, and was fed through dry feed machines. The first season was rather haphazard as many difficulties in mechanical operation had to be ironed out.

All operation with chemicals has been on an experimental basis, thus far, as we have been trying to find the best treatment as well as the most economical.

The results of chemical treatment during 1937 are summarized in Table I. The July results have been omitted as the flow meters were not in operation until July 23, 1937.

The October, 1937, results are divided into two periods, one with ferric chloride and lime and the other, October 9–31, with ferric chloride alone. It will be noted that chemicals were not used, except chlorine, during the late evening and early morning hours as the sewage is weak and the flow low.

The results with ferric chloride alone were better than with ferric chloride and lime so that it was decided to use this chemical during the summer of 1938.

The data for 1938 are summarized in Table II. A much more accurate control of the ferric chloride was maintained and most of our other mechanical difficulties had been eliminated. The data are divided into four periods, the first in July when a ferric chloride dosage of one grain per gallon was maintained; the second, August 1–15, when

TABLE I.—*Tests with Lime and Ferric Chloride and Ferric Chloride Alone*

1937

Operating Data

Date	Sewage Flow M.G.D.	Detention Periods		Hours Chemicals Applied	Lb./M.G.	
		Flocculators Min.	Imhoff Tanks Hours		Lime	Anhy. $FeCl_3$
August	4.38	35.5	2.1	14.6	277	80
Sept.	3.68	40.3	2.7	14.6	206	100
Oct. 1–8	3.72	31.8	5.1	15.0	220	106
Oct. 9–31	3.35	46.7	5.6	14.7	—	184

Chemical Data *

Date	Turbidity			5-Day B.O.D.			Suspended Solids		
	P.p.m.		% Red.	P.p.m.		% Red.	P.p.m.		% Red.
	Raw	Eff.		Raw	Eff.		Raw	Eff.	
August	161	93	42.2	181	80	55.8	237	42	82.2
Sept.	163	74	54.5	199	77	61.3	194	34	82.5
Oct. 1–8	197	93	52.8	212	82	61.3	253	42	83.4
Oct. 9–31	170	76	55.3	201	70	65.0	177	41	76.8

* Analyses were made on the final effluent which had been chlorinated.

TABLE II.—*Tests with Ferric Chloride*

1938

Operating Data

Date	Sewage Flow		Detention Periods		Hours Chem. App.	Anhy. $FeCl_3$	
	M.G.D.	M.G. per Hr. Chem. Applied	Flocc. Min.	Imhoff Tanks Hours		Lb. per M.G.D.	Lb. per Hr. Chem. Applied
July 9–31	6.10	3.81	26.0	1.90	15.5	69	109
Aug. 1–15	4.04	2.74	37.5	2.23	14	180	272
Aug. 16–31	3.58	2.40	42.9	2.78	14	153	227
Sept. 1–14	5.89	3.91	30.1	1.92	19	90	115

Chemical Data *

Date	Turbidity			5-Day B.O.D.			Suspended Solids		
	P.p.m.		% Red.	P.p.m.		% Red.	P.p.m.		% Red.
	Raw	Eff.		Raw	Eff.		Raw	Eff.	
July 9–31	72	52	27.8	81	26	68.0	112	37	67.0
Aug. 1–15	101	50	50.5	144	42	70.7	157	32	79.6
Aug. 16–31	105	54	48.5	151	48	68.1	174	37	78.7
Sept. 1–14	92	58	37.0	117	38	67.5	146	40	72.6

* Analyses were made on the final effluent which had been chlorinated.

the dosage was 2 g/g; the third, when the dosage was 1.5 g/g; and the fourth when the dosage was again 1 g/g but the treatment was continued during the 24 hours of the day. These tests showed, conclusively, that the 1.5 g/g dosage was the best and that continuing the application of chemicals during the 24 hours did not appreciably improve the efficiency of the plant.

During the winter 1937–38 tests were made in the laboratory to determine the effect of various chemical coagulants. In these tests, two gallons of sewage were used, the samples were agitated rapidly (120 r.p.m.) for 5 minutes and slowly for 25 minutes (25 r.p.m.) and allowed to settle for two hours. These particular periods of flocculating and settling were used in order to duplicate, as nearly as possible, plant operation. Two control samples were used, one with 1 g/g of ferric chloride and the other with 2 g/g of alum. Tests were made using various ratios of ferric chloride and lime, ferric chloride alone, ferrisul, alum, and alum and silica. Most of the tests dealt with various ratios of alum and silica and it was demonstrated that alum and silica were very good coagulants.

The silica used was the 42 deg. Bé sodium silicate which was neutralized with sulfuric acid to obtain a so-called "active" solution and was diluted with water to obtain a 1.5 per cent solution of sodium silicate. In the plant a 3 per cent solution of sodium silicate was prepared. (For the preparation of the "active" sodium silicate solution see the article by Mr. John R. Baylis in *Water Works and Sewerage* for June, 1937 (Volume 84, pages 221–225).)

To bear out the laboratory findings, a plant scale experiment was made in May, 1938, using alum and silica which was supplied through the generosity of the General Chemical Company. This test was run for six days, during which time the following dosages of alum and silica were used:

May 11 and 12,	0.2 g/g SiO_2 + 1 g/g alum
May 13,	0.4 g/g SiO_2 + 2 g/g alum
May 14,	0.2 g/g SiO_2 + 1.5 g/g alum
May 17,	0.4 g/g SiO_2 + 2 g/g alum
May 19,	0.2 g/g SiO_2 + 1.5 g/g alum

The results of this test were encouraging but did not seem to be better than the results with ferric chloride. The plant tests with ferric chloride were then made, as previously described, and in September a seven-day test was again made with alum and silica. This time, 0.2 g/g SiO_2 and 1.5 g/g of alum was used throughout the course of the test and, as will be noted in Table III, the results were superior to those with ferric chloride.

In October, 1938, a ten-day test was made with alum alone, using 2 grains per gallon. The results are also shown in Table III. The reductions in B.O.D. and suspended solids on unchlorinated effluents were comparable to those with alum and silica in the test made during May.

TABLE III.—*Tests with Alum and Sodium Silicate, and Alum Alone*

1938

Operating Data

Date	Sewage Flow		Detention Periods		Hr. Chem. App.	Lb./M.G.D.		Lb./Hr. Chem. Applied	
	M.G.D.	M.G. per Hour Chem. App.	Flocc. Min.	Imh. Tks. Hr.		Sod. Sil.	Alum	Sod. Sil.	Alum
May* 11–14, 17 and 19	3.26	1.93	41.9	2.83	12.6	27	149	44	244
Sept. 24–30	5.76	3.76	23.0	2.91	14	57	139	89	214
Oct.† 5–13, and 16	3.74	2.40	40.4	2.41	14.4	0	188	0	293

Chemical Data

Date	Turbidity			5-Day B.O.D.			Suspended Solids		
	P.p.m.		% Red.	P.p.m.		% Red.	P.p.m.		% Red.
	Raw	Eff.		Raw	Eff.		Raw	Eff.	
May* 11–14, 17 and 19	177	88	50.3	197	87	55.8	191	50	73.8
Sept. 24–30	95	36	62.0	139	34	75.5	138	22	84.0
Oct.† 5–13, and 16	114	66	42.1	156	66	57.7	151	41	72.8

* Unchlorinated effluent. Test was run using a different amount of alum and silica each day in order to determine the minimum amount of each chemical for the best treatment. On this basis the entire test in September was made using 0.2 g/g SiO_2 and 1.5 g/g of alum.

† Unchlorinated effluent.

The floc with alum and silica is very large whereas that with alum alone is fine.

This summer we paid \$2.25/cwt. for anhydrous ferric chloride, delivered to our plant, and on this basis the cost per million gallons for a treatment of 1.5 g/g would be \$4.88.

The cost of alum delivered to our plant in carload lots would be \$1.16/cwt., sodium silicate \$1.23/cwt. and sulfuric acid, \$2.22/cwt. On the basis of 1.5 g/g alum + 0.2 g/g SiO_2, our cost for this treatment would be:

Alum	\$2.50/m.g.	(1.5 g/g)
Sodium Silicate	1.08/m.g.	(0.2 g/g SiO_2)
Sulfuric Acid	0.275/m.g.	
Total	\$3.855/m.g.	

The cost of alum alone (2 g/g) would be \$3.32 per million gallons.

The results indicate that, for our sewage, the use of 1.5 g/g of alum + 0.2 g/g SiO_2 is the best treatment at the present time.

Table IV gives a summary of the monthly averages for eighteen months of operation. This gives a good indication of the effect of chemical treatment as compared with plain sedimentation in Imhoff tanks.

TABLE IV*A*.—*Monthly Averages of Operating Data*

Month	Sewage Flow M.G.D.	Detention Periods			pH		Remarks
		Flocc. Min.	Imhoff Tanks Hours	Contact Tank Min.	Raw	Eff.	
1937							
July	4.19	36.5	3.3	27.5	7.4	7.1	$FeCl_3$, 22 days. Lime + $FeCl_3$, 9 days. Cl_2, 28 days
Aug.	4.38	35.5	2.1	26.9	7.4	7.2	Lime + $FeCl_3$, entire month. Cl_2, entire month
Sept.	3.68	40.3	2.7	30.4	7.4	7.2	Lime + $FeCl_3$, entire month. Cl_2, 26 days
Oct.	3.45	42.1	5.3	0	7.6	7.2	Lime + $FeCl_3$, 8 days. $FeCl_3$, 23 days
Nov.	3.83	39.7	3.3	0	7.6	7.2	$FeCl_3$ used only 3 days
Dec.	4.11	36.8	4.4	0	7.5	7.2	No chemicals used
1938							
Jan.	5.09	34.4	4.1	0	7.5	7.1	No chemicals used
Feb.	6.56	0	3.2	0	7.4	7.2	No chemicals used. Flocculators used only 2 days
Mar.	4.86	0	4.0	0	7.6	7.2	No chemicals used
Apr.	4.11	0	4.5	0	7.5	7.2	No chemicals used
May	3.33	34.1	3.2	0	7.6	7.2	Alum + SiO_2, 6 days. Flocculators, 20 days
June	4.73	27.0	2.4	31.0	7.3	7.2	$FeCl_3$, 6 days. Cl_2, 12 days
July	7.61	23.0	1.8	16.7	7.3	7.2	$FeCl_3$, 24 days. Cl_2, entire month
Aug.	3.78	40.2	2.6	29.4	7.3	7.1	$FeCl_3$ and Cl_2 used entire month
Sept.	6.20	26.5	2.0	19.4	7.4	7.2	$FeCl_3$, 13 days. Alum + SiO_2, 7 days. Cl_2, 22 days
Oct.	3.59	39.3	2.8	0	7.4	7.2	Alum + SiO_2, 4 days. Alum, 11 days. $FeCl_3$, 1 day. Cl_2, 1 day. Flocculators, 19 days
Nov.	3.21	0	4.6	0	7.5	7.3	No chemicals
Dec.	3.03	0	6.1	0	7.6	7.3	No chemicals

TABLE IVB.—*Monthly Averages of Chemical Data*

Month	Turbidity			5-Day B.O.D. at 20° C.			Suspended Solids			Nitrogen as N P.p.m.					
	P.p.m.		Per Cent Red.	P.p.m.		Per Cent Red.	P.p.m.		Per Cent Red.	Total		Org.*		Ammonia	
	Raw	Eff.		Raw	Eff.		Raw	Eff.		Raw	Eff.	Raw	Eff.	Raw	Eff.
1937															
July	—	—	—	159	71	55.3	169	39	77.0	—	—	—	—	—	—
Aug.	161	93	42.2	181	80	55.8	237	42	82.2	—	—	—	—	—	—
Sept.	163	74	54.5	199	77	61.3	194	34	82.5	—	—	—	—	—	—
Oct.	177	80	54.8	204	73	64.2	197	42	78.7	—	—	—	—	—	—
Nov.	199	112	43.7	236	122	48.3	234	66	71.8	—	—	—	—	—	—
Dec.	—	—	—	248	126	49.1	282	64	77.4	—	—	—	—	—	—
1938															
Jan.	—	—	—	191	102	46.5	225	63	72.0	—	—	—	—	—	—
Feb.	—	—	—	106	64	39.6	158	59	62.7	—	—	—	—	—	—
Mar.	—	—	—	145	87	40.0	184	54	70.6	—	—	—	—	—	—
Apr.	—	—	—	127	69	45.7	210	47	77.6	17.2	14.9	6.9	4.0	10.3	10.9
May	149	96	35.6	186	95	48.9	188	65	65.4	23.3	21.8	7.5	3.7	15.8	18.1
June	107	71	33.6	138	62	55.0	182	48	73.6	18.7	16.6	6.3	4.0	12.4	12.6
July	66	50	24.2	71	24	66.2	108	38	64.8	10.3	10.4	3.3	3.0	7.0	7.4
Aug.	103	52	49.5	148	45	69.5	166	35	79.0	20.2	18.0	7.7	3.1	12.5	14.9
Sept.	83	49	41.0	110	38	65.5	133	38	71.5	15.0	14.8	7.3	4.5	7.7	10.3
Oct.	137	76	44.5	182	83	54.4	177	47	73.4	23.1	21.7	8.1	4.8	15.0	16.9
Nov.	—	—	—	196	107	45.4	184	53	71.1	26.1	24.9	10.6	7.3	15.5	17.6
Dec.	—	—	—	216	116	46.3	210	46	78.0	29.6	25.6	19.9	14.9	9.7	10.7

* By difference.

FIRST YEAR'S OPERATION OF WARDS ISLAND SEWAGE TREATMENT WORKS*

By Wellington Donaldson

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The Wards Island Project (Fig. 1), comprising 6¾ miles of main intercepting sewers in Manhattan, 2½ miles of main intercepting

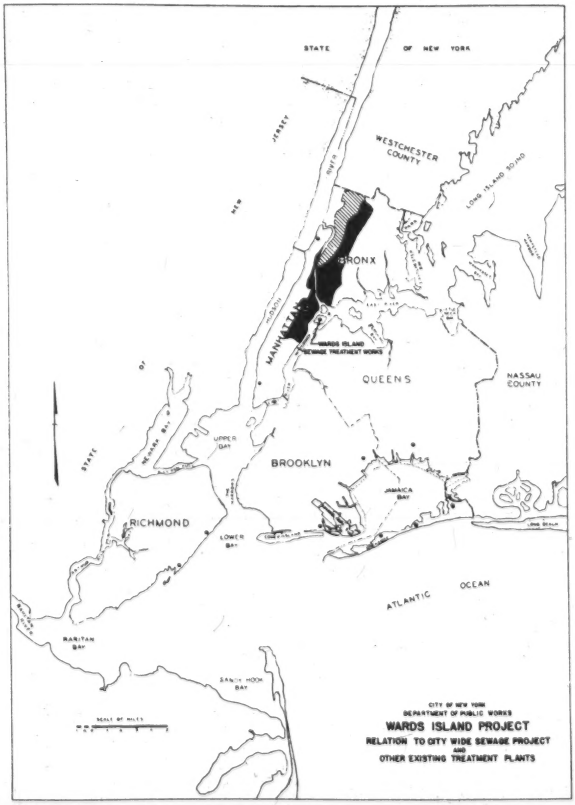

FIG. 1.—Wards Island project as related to existing treatment plants of New York City.

* Presented at the Eleventh Annual Meeting of the New York State Sewage Works Association, New York City, Jan. 20, 1939.

sewers in the Bronx, two grit chambers, tunnels under the river, treatment works proper on Wards Island and a fleet of three sludge vessels, represents the second and most important step in the comprehensive program for adequate treatment of the sewage of New York City. The treatment processes employed provide a higher degree of treatment than those used at the Coney Island Plant and far superior to that of the screening plants which, until 1935, represented the best effort towards sewage treatment in the City.

The Wards Island Plant treats by the activated sludge process the sewage from a population of approximately 1,200,000. This population is practically equivalent to that served by the North Side Plant of The Sanitary District of Chicago, or the Mogden Plant of the West Middlesex drainage district in England. These three plants stand out as the major sewage treatment works of the world now in operation, although soon to be exceeded by the new Southwest Plant of the Chicago Sanitary District.

Most of the sewers tributary to the plant are on the combined system, hence the interceptors are equipped with regulating chambers, 52 on the Manhattan side and 8 on the Bronx side, designed to reject in excess of twice the dry weather flow, estimated at 180 m.g.d. The Manhattan grit chamber, located at 110th Street and the East River Drive, and the Bronx grit chamber, located at 132nd St. and St. Ann's Avenue, are integral parts of the Wards Island System and their separate crews are under the management of the Superintendent of the Wards Island Plant. At each of the grit chambers, floating material such as rags, sticks, etc., is removed by rack and mechanical bar screens and the grit is removed by settling in mechanically cleaned channels before the sewage flows by gravity through tunnels in the rock to Wards Island. There the sewage is lifted by pumps to the treatment plant, which comprises preliminary sedimentation, activated sludge aeration and final settling (Fig. 2). The effluent is discharged into the East River at Hell Gate.

History of Project

The Metropolitan Sewage Commission, in its 1914 report, recommended Wards Island as the appropriate site for a sewage treatment plant. In 1927, the City acquired the present plant site on the north end of Wards Island by an Act of Legislature transferring this state-owned property. Not having at that time a design force experienced in sewage treatment, the City employed in 1928 the firm of Fuller and McClintock to design the works. The project report and plans were submitted in March, 1929 and approved by the Board of Estimate and Apportionment on October 3, 1929, when authorization was given for contract drawings and specifications. Construction work on Contracts A (dock and seawall), and B (tanks and operating galleries), started June, 1931, and these contracts were completed early in 1933. The project then halted for lack of funds after an expenditure of $4,500,000. In

1935, the City secured a P.W.A. grant of 45 per cent, amounting to about $11,000,000 and construction was resumed in September, 1935, simultaneously on the intercepting sewers, grit chambers, tunnels under the river, superstructures and machinery. Sewage was first turned into the plant October 18, 1937 and the formal dedication occurred October 23rd.

Until late in August it was understood that the plant would be completed and ready for operation in December. The advanced opening date brought great pressure on the construction forces to complete the structures on time, and further pressure on the operating organization to build up an operating personnel adequate to handle the plant. That both of these objectives were attained is a fine tribute to the cooperation between the contractors, department engineers and the operating force.

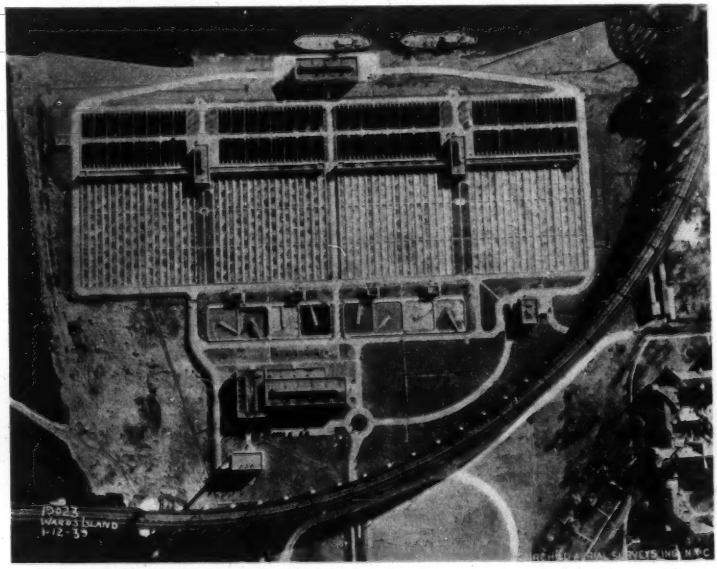

FIG. 2.—Aerial view of Wards Island Plant, as of Jan. 12, 1939.

OPERATING ORGANIZATION

Visitors from other cities frequently ask about the make-up of the operating organization of the treatment plants of New York City. All employees of the City are certified by the Municipal Civil Service Commission. Until the Wards Island Plant was put in service, the operating force of sewage treatment plants, with a few exceptions, fell into three classes (a) stationary engineers (electric); (b) oilers and (c) laborers. Basically, then, the responsible plant operating man, or

watch engineer is the stationary engineer (electric). His qualifications call for experience in the installation, operation, maintenance and adjustment of electrically driven machinery, and of switchboards and appurtenances. Some of the men holding this title have been promoted from the ranks, others have come into the department after experience with subway and utility power plants. A number of them have college degrees in electrical engineering. Until recently, all stationary engineers were all on a basis of $9.00 per diem and worked 8 hours per day, 7 days per week. The building of new plants has brought recognition of the need of greater rewards to those in responsible positions and has resulted in the establishment of salaries of $3750 and $4000 per year for the top watch engineers. Oilers in the department get $7.00 and laborers $5.50 per diem. The opening of the Wards Island System brought into city service a number of new titles not formerly required. The complete list of the operating personnel of Wards Island by titles and number of incumbents is given in Table I, while the distribution of this personnel by location is shown on the chart (Fig. 3).

It should be remembered that the Wards Island Project is quite extensive. First, there are the intercepting sewers in Manhattan and the Bronx, with regulators which require continual inspection and maintenance. Each of the two grit chambers is in reality a separate sewage treatment plant handling about 100 m.g.d. The plant on Wards Island covers an area of 52 acres and requires a considerable subdivision of the force to man the various locations; (1) central heating plant; (2) pump and blower house; (3) preliminary pumping stations; (4) return sludge pumping stations, aeration tanks and final tanks; (5) sludge storage building; (6) the fleet of sludge vessels; (7) administration building and laboratory. The administrative office of the Section of Sewage Disposal Operation which has supervision over all treatment plants in the five boroughs of the City is at present located in the administration building. In Table I, the general administrative organization is not included.

During the first year's operation the number of watch engineers provided has been fairly adequate except for vacation relief, when it has been necessary to cripple some of the other plants to find replacements. The labor quota for this plant, however, has been continually inadequate to cover the large areas of tanks and the different locations. All available labor has been kept too busy on necessary operations to give proper attention to the ordinary jobs of housekeeping necessary to keep a plant tidy and presentable.

Operating Difficulties

When sewage was first turned into the intercepters, the operating troubles were concentrated at the two grit chambers on account of the great quantities of materials other than of sewage origin which had to be handled by the screens and grit removal mechanisms, particularly at the Bronx grit chamber, where its was found that one of the principal

TABLE I.—*Operating Personnel, Wards Island*

Title	Number	
Superintendent (Sewage Treatment Operations)	1	
Stationary Engineer, Electric (Chief Engineer)	1	
Stationary Engineer, Electric (Senior Engineers)	3	
Stationary Engineer, Electric	12	
Stationary Engineer, Steam	3	
Crane Engineer, Electric	1	
Electrician	1	
Machinists	2	
Engineer Inspector	1	
Oilers	12	
Laborers	65	
Cleaners	1	
Auto-Enginemen	2	
Clerks	3	
Stenographer and Typist	1	
	—	109
Laboratory		
Principal Chemist (Sanitary)	1	
Bacteriologist	1	
Assistant Chemist	1	
Laboratory Assistant	2	
	—	5
Sludge Vessels		
Captains	3	
First Mates	3	
Second Mates	2	
Chief Engineer (Diesel)	3	
First Assistant Engineer (Diesel)	3	
Second Assistant Engineer (Diesel)	2	
Marine Oilers	11	
A. B. Seamen	16	
Cooks	3	
Mess Men	3	
	—	49
Total		163

tributary trunk sewers had never been cleaned and after each rain discharged avalanches of sand, grit, coal, scrap iron, timbers, etc., which put out of commission the cleaning mechanisms and made necessary an extraordinary amount of hand labor.

Visitors to the plant last January (1938) at the time of the Annual Meeting of the New York State Sewage Works Association, saw the preliminary settling tanks on Wards Island covered with a thick scum, with which the scum removal mechanisms of the tank were unable to cope. A later study of this problem developed the fact that air entrained in the downtake shafts of the inverted siphons between the grit chambers and Wards Island was being released as fine bubbles in the preliminary settling tanks and acted as a flotation agent to bring to the surface material which ordinarily would be captured as sludge. By carrying a higher level of sewage in the suction well and thereby a higher level in the entrance shafts, the entrained air was excluded and

the extraordinary accumulation of scum on the preliminary tanks was avoided.

The pumping of sludge from the preliminary tanks to the storage tanks on the dock has been the chief source of operating annoyance. In each of the four preliminary pumping stations are three reciprocating plunger pumps, each with a nominal capacity of 130 g.p.m. against a 45 ft. head. On account of the nature of the primary sludge captured in the preliminary tanks, these pumps have been hard pressed to hold down the sludge level in the preliminary tanks. Four additional pumps, each with a capacity rating of 300 g.p.m. against 160 feet head, are being installed to supplement the original pumps, and it is hoped thereby to alleviate the troubles mentioned.

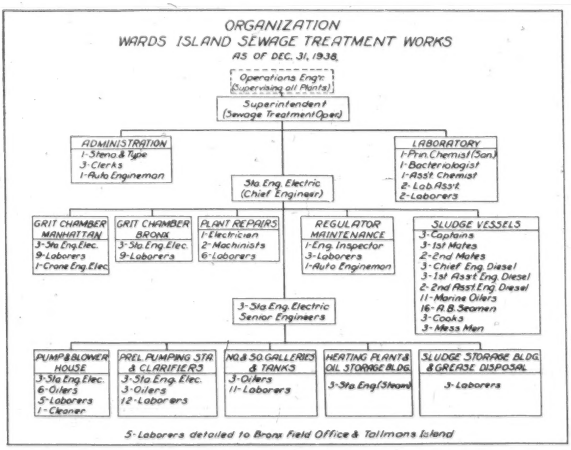

FIG. 3.—Organization chart of operating personnel.

Since the sludge vessels are an integral part of the Wards Island Plant, a list of operating troubles should not omit passing reference to the "navy." It appears that vessels continually maneuvering in harbor traffic lanes are subject to the same hazards as automobiles on busy highways, with the difference that it is more expensive to take out dents. The ratio of repairs to investment, however, is not disproportionate.

EXPERIENCES WITH EQUIPMENT

At the grit chambers, the nature of the service on combined sewage has involved much trouble with the mechanical equipment such as mechanically cleaned screens and grit-cleaning mechanisms. The service has been likewise hard on the grit pumps, grit washers and the pneumatic system which discharges the grit and screenings to the overhead

storage tanks. As a result of these experiences conveyor handling of grit at the Tallmans Island Plant has been substituted for grit pumping.

There has been little trouble with the main pumps at Wards Island, the only exception being a "frozen" sleeve on one unit, which was promptly repaired by the makers. Likewise, the main blowers at Wards Island have operated with a minimum of trouble. Structural defects on the motor end of blowers have necessitated correction. The preliminary sludge pumps have been subjected to hard, grueling service far beyond the work contemplated, hence depreciation and maintenance on these units has been very high.

Interruptions

Since sewage was turned into the plant on October 18, 1937, there have been a few instances of power failure of short duration which did not interrupt operations. On September 21, however, during the hurricane which touched New York and swept over Long Island and New England, a tidal wave caused the water in Hell Gate to rise to Elev. 9.0, Manhattan Datum. This put out of commission the Hell Gate plant of the Edison Company and caused a shut-off of power for 1.3 hours. During this period, with the main pumps on the island shut down, it was necessary to isolate the grit chambers and by-pass the sewage through the regulators and storm outlets into the Harlem River.

Concentration of Excess Activated Sludge

Regardless of the disposition of excess sludge, whether by dumping at sea, digestion or dewatering by vacuum filters, there is always the problem of restricting to a minimum the volume of excess sludge handled. Two of the 32 final settling tanks at Wards Island are arranged for sludge concentration and ordinarily serve satisfactorily. At times, however, it has been necessary to waste activated sludge to the inlet of the preliminary tanks. Application of copper sulfate to the influent of the concentration tanks did not prove helpful, within economic limits. Equipment is now installed for chlorinating the sludge entering the concentration tanks, but results of this treatment are not yet available.

Odor Control

Operation of modern sewage treatment plants without unsightliness or unpleasant odors is a fundamental requirement if a sympathetic public interest is to be enlisted in these necessary municipal enterprises. As the Wards Island Plant is strategically located under the Triboro Bridge, and is subjected to the observation of thousands of citizens daily who pass over the bridge, it is especially important that no effort be omitted to prevent criticism on account of unpleasant odors. The waste sludge of the Wards Island Plant is stored in large tanks in a building on the waterfront until it can be taken away to sea. The storage of large quantities of sludge in this manner, especially in the sum-

mertime, is a potential source of nuisance. As a matter of fact, during the early spring and summer of 1938, complaints were received not only from the adjacent hospital on Wards Island but from the residents of Astoria across the East River.

To control the odors at the Wards Island Plant a system of odor control has been installed which is believed to be unique in American sewage treatment practice, although successful use of ozone for odor elimination was reported at Johannesburg, South Africa, in the 1937 Annual Report of the City Engineer. No details of the Johannesburg installation have been available to us, but it is assumed that the system used at Wards Island differs in the equipment employed and particularly in the use of activated carbon to supplement ozone.

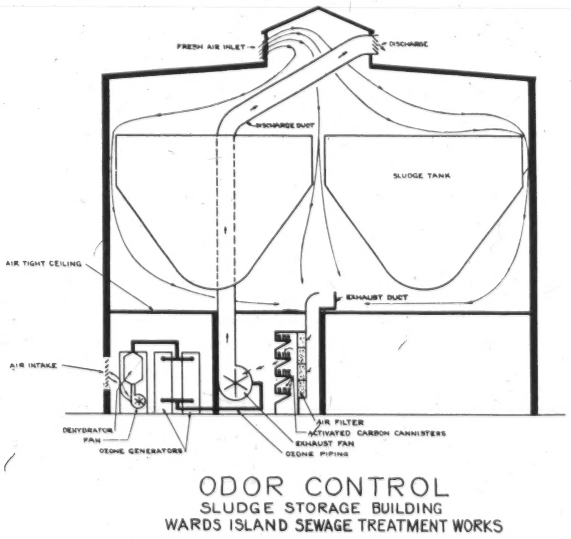

FIG. 4.—Odor control, sludge storage building.

Figure 4 shows diagrammatically the arrangement at the sludge storage building whereby air is drawn by forced draft through monitors on top of the building, and sweeps downward the odorous gases arising from the sludge storage tanks. The mixed gases are drawn through canisters of activated carbon, then dosed with ozone before discharge to the roof of the building. A view of ozone equipment is shown in Figure 5, while Figure 6 shows diagrammatically the arrangement of the ozone generator.

The equipment with a rated capacity of 61 grams of ozone per hour was found on test to deliver 56 grams per hour with a freshly regen-

erated dehydrator. During humid weather the yield dropped to 42 grams per hour after 24 hours of service. The ventilating fan has a

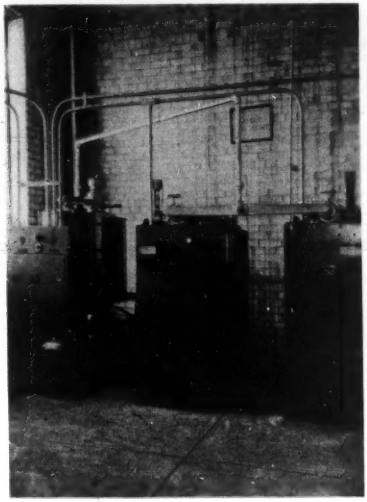

FIG. 5.—Ozone generators—view.

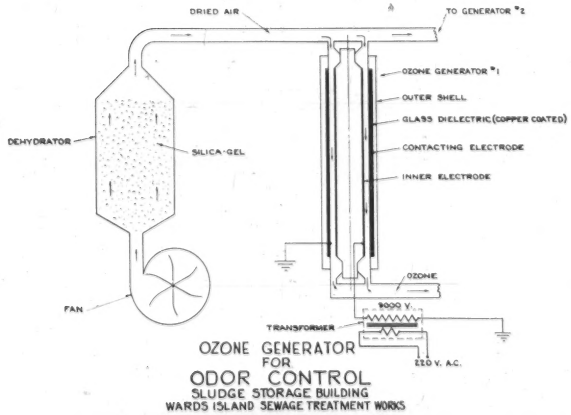

FIG. 6.—Diagram of ozone generator.

capacity of 15,000 cu. ft. per minute, representing a displacement of air in the upper part of the sludge storage building each half hour. With ozone shut off, the activated carbon was found to accomplish a substan-

tial but not complete removal of odor. The addition of ozone seems to complete the job.

To take care of the odors originating from loading the vessels and transporting the sludge to sea, the gas vents of the storage tanks of the three vessels have been equipped with a system of activated carbon absorption as shown in Figure 7.

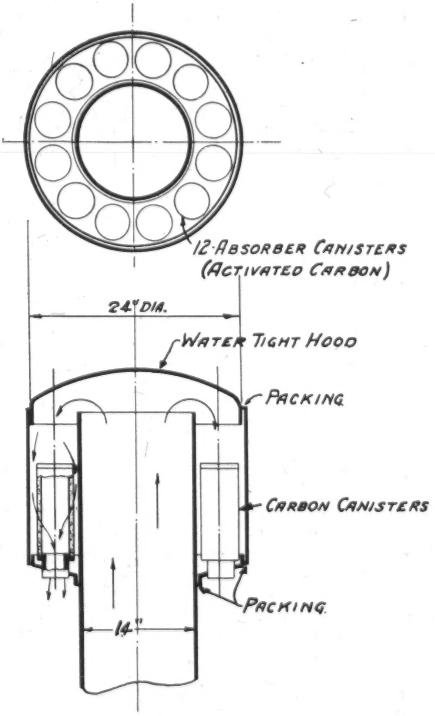

Fig. 7.—Activated carbon canisters on sludge vessels.

Disposal of Materials Removed from Sewage

The grit and screenings removed at the grit chambers are taken away by the Department of Sanitation trucks for disposal by fill or incination, respectively. Each of the grit chambers is provided with hammer-mill equipment for disintegrating the material captured by

the mechanical screens, and delivering the comminuted material to the sewage flow. There is also a provision for transporting the screenings separately by belt conveyor and pneumatic ejectors to storage bins. Both methods have been used at the grit chambers, but the second method is the one now practiced, for it has been concluded that the return of comminuted screenings results in more bother at Wards Island, on account of rags and floating material.

All of the sludge from the preliminary tanks is pumped to the storage tanks at the water front and thence discharged by gravity into the sludge vessels. The excess activated sludge has at times been pumped separately to the sludge storage tanks, mixed with the primary sludge, and sent to sea. At other times, due to difficulties in adjusting sludge vessel schedules, or to the unusual volumes of sludge to be handled, excess activated sludge has been returned to the head of the plant and thereby captured and pumped with the primary sludge to the storage tanks.

When the plant was laid out ten years ago, it was contemplated that the scum collected from the primary tanks would be sent to sea with the sludge, hence two separate storage tanks were provided in the sludge storage building for handling the scum in this manner. During the past decade, ideas of what material is permissible to be dumped at sea off shore have undergone considerable change. Sludge settles and disappears quickly, but grease has a tendency to form sleek areas of wide extent, consequently another method of disposing of grease and scum had to be contrived. The department has, therefore, designed and installed a system for disposal of grease by incineration. Figure 8 shows diagrammatically the arrangement installed in the sludge storage building. The grease separates to the top, on standing, and the liquor underneath is "subcanted" back to the head of the plant. In the course of a week or ten days, there is a sufficient accumulation of grease to justify firing the incinerators and burning the grease. The oil fired incinerators have also been found useful in disposing of the rubbish, rags and other material collected at the plant. Since combustion temperatures of 1800 deg. F. are maintained, there is no odor nuisance from the incinerators.

Sea Disposal of Sludge

The disposal of sewage sludge at sea is an uncommon but not rare practice for American cities on the seaboard. It is practiced at Providence, R. I. (dewatered filter cake), New Haven, Conn., Passaic Valley, N. J., Elizabeth, N. J. and New York City. The dumping of sludge in coastal waters is governed by regulations of the War Department which has designated for the New York area a location eight miles ESE of Scotland Light, which means about twelve miles off the Long Island and New Jersey shores. The distance of the "dumping ground" from the Wards Island Plant by water is 34 miles. For dumping sludge, a permit is required from the War Department each half month, in which must be stated the nature and quantity of the materials to be dumped.

After each trip a certificate must be surrendered to the patrol boat of the Supervisor of the Harbor.

For transporting sludge from the Wards Island Plant, the City has had constructed three specially designed sludge vessels. The organization of the special marine service for disposing of the sludge from Wards Island has been second in importance only to placing the treatment plant itself in operation. The demands for making the service effective have been very exacting because of the necessity of reconciling Federal marine regulations with local harbor customs and variable treatment plant requirements for sludge disposal. As the City's sludge vessels were not completed in time for initial operations on Octobr 18,

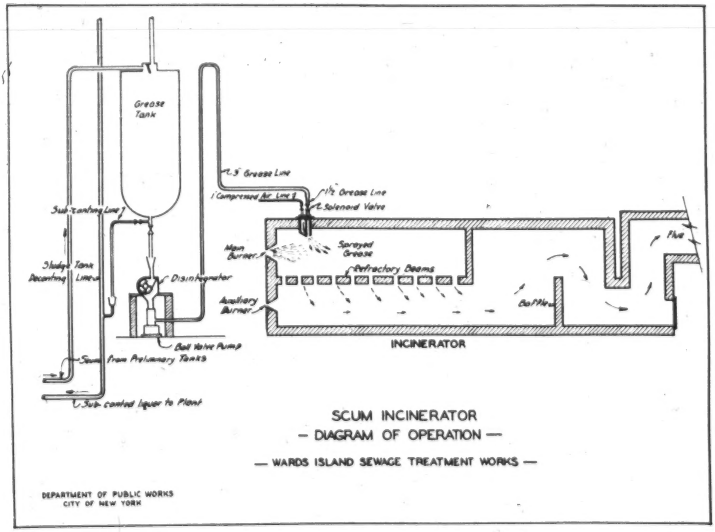

FIG. 8.—Diagram of grease incineration system.

1937, a contract was made with the Merritt, Chapman and Scott Corporation to barge the sludge to sea, as is done with the sludge from the New Jersey communities named above. This service was rendered until January 17, 1938, when the first of the City's vessels became available.

The three sludge vessels, namely the "Wards Island," "Tallmans Island" and "Coney Island," were built for the City as part of the Wards Island contract by the United Shipyards, Inc. at a combined cost of $1,497,000. They are steel hulled vessels identical in design, 257 ft. 3 in. in length, 43 ft. 6 in. in beam, with loaded draft of 11 ft. and gross displacement of 1429 long tons. Each vessel has a sludge

cargo capacity of 55,000 cu. ft. The vessels are twin screw, diesel powered (715 HP each engine) and are capable of a speed of 11 knots. Figure 9 shows one of the sludge vessels cruising up East River. The vessels are completely equipped for sea duty and have living quarters aboard for the entire personnel. Two of the vessels are kept in active service. Together they now make an average of three trips per day.

FIG. 9.—Sludge vessel passing up East River.

The round trip of 68 miles requires 6 to 7 hours. The third vessel is held in reserve at the dock for maintenance and repairs and alternates in active service with the other boats. The entire marine personnel is shown in Table I and on the organization chart, Figure 3. The roster for a single boat on active duty is as follows:

	No.	Monthly Rate*
Captain	1	$275.00
First Mate	1	200.00
Second Mate	1	180.00
A. B. Seamen	6	105.00
Chief Engineer (Diesel)	1	250.00
First Asst. Engineer (Diesel)	1	200.00
Second Asst. Engineer (Diesel)	1	180.00
Oilers (Marine)	4	115.00
Cook	1	115.00
Messman	1	65.00
Total	18	

* Exclusive of subsistence.

Each of the marine personnel works six days per week. Replacements for the day off and sick leaves are made from the vessel held in reserve.

Subsistence of the men in the marine service is furnished by the City on the basis of eighty cents per day per man on duty. The food is furnished from the Bellevue Hospital Storehouse and is carefully inspected by the Department of Purchase. The sludge vessels, being subject to service 24 hours a day, are operated on a definite schedule. The personnel are assigned to sea watches according to marine regulations. During 1938, the three sludge vessels made 723 trips with total cargo of 39,456,000 cu. ft. of sludge, varying from 2.0 to 5.0 per cent solids, exclusive of 744,000 cu. ft. removed in January by contract.

Treatment Data

The principal operation results of the plant during 1938 are summarized in Table II. For proper evaluation of these data certain facts must be borne in mind. The plant went into service in October, 1937, with only the preliminary tanks in use. A single battery of aeration tanks was soon put into service. Additional aeration units were progressively added as construction work was completed. It was not until March 7th that the fourth and final battery of aeration tanks was available for service, thus permitting full treatment to all sewage pumped at the Island. Also it was not until June 24th when cleaning of one of the main trunk sewers in the Bronx (Brook Ave.) was completed, that the entire sewage tributary to the intercepters was handled by the plant. The quantity of effluent subjected to primary treatment only is represented by the differences in the first two columns of the table. The figures in the first column are monthly averages. Actually the pumpage at Wards Island during the year has ranged from about 65 to 400 m.g.d., with a recorded maximum of 438 m.g.d.

The suspended solids and B.O.D. in the activated sludge effluent averaged 15 p.p.m. and 16 p.p.m., respectively (Table II). If account be taken of the primary effluent not subjected to aeration, the over-all effluent figures, weighted for relative flows, were 26 p.p.m. and 30 p.p.m., respectively.

Regarding "sludge index" figures shown in Table II the author is old fashioned enough to prefer his method of expression, reported in 1932 (*This Journal*, 4: 48) rather than the reciprocal expression proposed by Mohlman in 1934 (*This Journal*, 6: 119) and now incorporated in Standard Methods. The "sludge index" has varied from a minimum of 0.51 to a maximum of 1.83 during the year, as shown by the daily records.

Treatment Costs

Unfortunately at this time it is not possible to give the treatment costs for the entire twelve months of 1938 corresponding with the treatment results in Table II. In Table III are given the costs of operation

TABLE IIA.—*Ward's Island Sewage Treatment Works, Operating Data, Summary, 1938*

Month	Sewage Treated M.G.D.		Screenings			Grit—Cu. Ft.		Air Cu. Ft. Per Gal.	% Return Sludge	Sludge Index	Settling Rate Final Tanks Gal./ Sq. Ft.	Total Power		Susp. Solids		B.O.D.		Total Sludge to Sea	
			Wet Tons	Est.* Cu. Ft.		Total	Per M.G.					Ave. K.W.H./ Day	K.W.H. Per M.G.	Raw	Aer. Eff.	Raw	Aer. Eff.	Thous. Cu. Ft.	Dry Tons
	Prim.	Aer.		Total	Per M.G.														
Jan.	148	85	81.6	3,260	0.7	14,698	3.2	—	42	1.29	703	99,000	696	283	14	205	22	1,431	—
Feb.	140	87	69.8	2,800	0.7	12,786	3.3	—	42	0.76	714	94,000	677	260	17	215	16	1,968	—
Mar.	148	126	145.9	5,850	1.3	15,002	3.3	—	43	1.23	644	110,000	748	229	21	241	24	2,958	—
Apr.	149	148	233.0	9,300	2.1	20,584	4.6	1.13	46	0.73	607	133,000	902	204	14	263	21	3,499	—
May	150	144	207.3	8,300	1.8	9,028	1.9	1.08	43	0.90	637	125,000	833	243	12	221	18	2,945	3,329
Jun.	178	176	190.7	7,650	1.4	10,201	1.9	0.86	29	1.14	725	119,000	684	275	17	149	11	2,182	3,559
Jul.	210	200	192.1	7,700	1.2	18,841	2.9	0.72	20	1.16	830	119,000	570	179	8	113	9	3,272	4,549
Aug.	195	194	195.8	7,850	1.3	12,204	2.0	0.74	25	1.40	800	119,000	614	203	10	137	12	4,162	3,856
Sep.	186	177	215.0	8,600	1.5	13,446	2.4	0.77	26	1.47	784	118,000	657	236	16	177	18	3,350	3,265
Oct.	172	166	246.5	9,800	1.8	12,335	2.3	0.98	29	1.03	713	136,000	795	222	17	225	18	4,430	3,923
Nov.	178	170	231.6	9,260	1.7	12,370	2.3	1.05	38	0.99	709	142,000	806	203	16	180	11	4,920	3,958
Dec.	177	166	318.1	12,700	2.3	13,325	2.3	0.82	33	1.05	687	116,000	655	199	21	170	19	4,965	3,982
Ave.	169	153	194.0	7,760	1.5	13,735	2.7	0.91	35	1.10	713	119,000	704	228	15	191	17	3,340	3,800

* Estimated at 50 lbs. per cubic feet.

TABLE IIB.—*Wards Island Sewage Treatment Works, Suspended Solids (Monthly Avg.)* 1938

	Aeration Tanks P.p.m.	Return Sludge P.p.m.
Jan.	1900	5827
Feb.	1435	4214
Mar.	1331	3478
Apr.	1515	3510
May	1600	3496
June	1456	4271
July	1590	5550
Aug.	1300	4055
Sept.	1252	3676
Oct.	1472	5288
Nov.	1862	5642
Dec.	1529	4737
Average	1520	4480

TABLE IIC.—*Wards Island Sewage Treatment Works, Distribution of Power for 1938, Thousand K.W. Hrs.*

Month	Pumps	Blowers	Auxiliary	Total
Jan.	993	1,778	306	3,077
Feb.	811	1,568	246	2,625
Mar.	961	2,149	288	3,398
Apr.	936	2,671	369	3,976
May	863	2,692	317	3,872
June	937	2,380	266	3,583
July	1,158	2,281	262	3,701
Aug.	1,108	2,288	285	3,681
Sept.	1,111	2,248	227	3,585
Oct.	1,061	2,900	268	4,229
Nov.	1,016	2,948	298	4,262
Dec.	1,028	2,279	313	3,620
Total	11,983	28,182	3,445	43,609

TABLE III.—*Wards Island Sewage Treatment Works, Activated Sludge Process, Operation and Maintenance Cost, 1938, Six Months, January 1st to June 30th*

Month	Sewage Treated M.G.	Inter-ceptors	Grit Chambers	Plant	Sludge Vessels	Total	Cost Per M.G.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Jan.	4,583	$ 775.50	$ 5,180.23	$ 39,951.12	$11,437.56	$ 57,344.41	$12.51
Feb.	3,922	736.00	4,783.14	35,285.83	13,288.39	54,093.36	13.79
Mar.	4,590	1,070.50	5,553.51	47,453.18	17,394.82	71,472.01	15.57
Apr.	4,458	770.00	4,757.00	45,102.97	7,635.94	58,265.91	13.07
May	4,646	687.00	5,293.07	49,589.97	6,361.90	61,431.94	13.33
June	5,326	770.00	4,652.10	43,291.97	5,620.92	54,334.99	10.20
Total	27,525	$4,809.00	$30,219.05	$260,675.04	$61,739.53	$357,492.62	$ —
Avg. for 6 mos.	4,587.5	$ 801.50	$ 5,036.51	$ 43,445.84	$10,289.92	$ 59,573.77	$13.00

Estimated population served 1,165,000.

and maintenance during the first six months of 1938, and in Table IV are given the breakdown costs for salaries, power supplies, etc. It cannot be assumed that these cost figures, covering a period when the plant was in partial service and undergoing completion, are representative of normal operation. However, they are offered as a preliminary indication of what may be expected for an activated sludge plant of this magnitude.

TABLE IV.—*Wards Island Sewage Treatment Plant, Activated Sludge Process, Including Interceptors Grit Chambers and Vessels, Operation and Maintenance Cost, 1938, Six Months, January 1st to June 30th*

Month	Salaries and Wages	Barging Sludge to Sea Under Contract	Power	Supplies, Materials, Repairs and Misc.	Total Cost	Total Sewage Flow M.G.	Cost Per M.G.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Jan.	$ 21,581.68	$8,010.00	$ 23,294.75	$ 4,457.98	$ 57,344.41	4,583	$12.51
Feb.	21,477.64	—	19,771.73	12,843.99	54,093.36	3,922	13.79
Mar.	24,659.60	—	24,148.19	22,664.22	71,472.01	4,590	15.57
Apr.	22,850.98	—	27,060.62	8,354.31	58,265.91	4,458	13.07
May	23,749.04	—	28,294.28	9,888.62	61,931.94	4,646	13.33
June	23,888.23	—	27,324.42	3,122.34	54,334.99	5,326	10.20
Total	$138,207.17	$8,010.00	$149,893.99	$61,331.46	$357,442.62	27,525	$ —
Avg. for 6 mos.	$ 23,034.52	$ —	$ 24,982.33	$10,221.91	$ 59,573.77	4,587.5	$13.00

Estimated population served 1,165,000.

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Operators' Reports and Suggestions

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PACKING FOR PUMPS *

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All pumps, regardless of the make or the conditions under which they operate, are equipped with packing boxes. It is the function of the packing which is placed in these boxes to prevent air, water, oil or other liquids from escaping from the pump by accompanying the rotating shaft through the box. This has been accomplished with oiled hemp, rubber and other fabricated packings.

During the past ten years plastic packings have come into general use. Not only has a general purpose plastic packing been developed but packings can be obtained to suit any pumping requirement such as hot or cold water, saturated steam, acids, alkaline and caustic liquids, hot oils and for many other specific purposes. This fact should be kept in mind and a packing suited to the pumping requirements used.

The important features in the selection of stuffing box packings besides having a material suited to the pumping requirements are that it will not cause wear to moving rods or shafts, will operate with a minimum of friction and will prevent leakage for a considerable length of time as well as being easy to install. These are the advantages that will be obtained by using a good grade of either metallic or fabricated packings. Metallic packings usually consist of an anti-friction metal, such as lead, aluminum-foil or other soft metals, combined with an oil and mineral lubricant such as graphite. The lubricant will form a film or coating on the shaft or shaft sleeves, as the case may be, and between the shaft and the packing. This will reduce the friction and resulting wear to the metal and packing, allowing the stuffing box to run cool, which incidentally saves power.

There are many different types of metallic packing made with or without a fibrous core. All manufacturers endeavor to construct a material which will conform readily and evenly to the contour of the stuffing box and shaft and which will be plastic and resilient so that the pressure that is exerted by the packing gland will be evenly distributed to the whole mass. One type of packing on the market uses a lubricant called Meta-film which coats over the shaft sleeve and gives the rotating parts a lustrous polish, filling pits and scores which are not too deep, thus helping to reduce friction.

* Presented at the Fall Meeting of the California Sewage Works Association, Santa Barbara, Sept. 6, 1938.

When fabricated packings are used they must be lubricated with some type of graphite grease. This can best be accomplished by having an Alemite connection on the lantern rings so that occasionally soft grease can be forced in to form an additional lubricant for the packing, and to keep the packing soft and pliable.

Regardless of the type of packing used the most important feature is that the packing be installed properly. The packing rings must be carefully fitted to the shaft with the ends cut squarely to fit exactly as each ring is fitted around the shaft. If the packing is properly cut on a bevel, it will make a very satisfactory job although we have found that by cutting the ends at right angles we have obtained the best results. In inserting the packing in the stuffing box only one or two rings of packing should be inserted at a time, care being taken that the joints of each ring are in a different position on the shaft to prevent leakage in the joints and through the packing. The faced ends of each ring should come squarely together when the ring is tight around the shaft. As the packing is inserted it should be securely compressed into the bottom of the box by means of followers and thoroughly pressed into the glands before subsequent rings are added. It is advisable to rotate the shaft one-quarter turn as each application of packing is inserted so that adhesion of the packing to the shaft is broken. This procedure will permit the pump to start more easily when placed in operation.

It is very important that the position of the lantern ring should be slightly forward from the inlet circulating pipe. This will permit the lantern ring to continue to function without being pushed past the opening when the packing gland has been subsequently tightened. After packing, the gland must not be drawn up too tightly. The best adjustment is indicated by a slight leakage of liquid from the stuffing boxes. Excessive pressure on the packing will cause scoring of the shaft-protecting sleeves and rapid deterioration of the packing itself. If the nuts are left finger-tight it is usually sufficient.

To obtain the most satisfactory operation of any type of packing, it is of course absolutely necessary that the shaft should run perfectly true and without any vibration. If either the shaft or the shaft sleeves are slightly out of round or badly pitted no type of packing will work entirely satisfactorily. Every effort should first be made to insure the smooth operation of the shaft sleeve to be packed. In case these are out of round they should be accurately ground to get them perfectly cylindrical before the pump is put in use. If this is not possible the best result can be obtained by using the softer type of packing with resilient cores which will hold better and conform to the irregularities more satisfactorily than solid metallic packing. However, on a shaft that is whipping badly an ordinary cotton type of packing will give as good service as any other type, especially if the shaft sleeves are scored. When this condition exists, if a harder metallic type of packing is used it will prove quite satisfactory when first installed. However, when it becomes necessary to compress the packing by tightening the glands, the packing will be pinched against the scores, causing the sleeves to thrust

to one side or the other, making the gland run excessively hot. When this happens the packing must be removed and re-packed with a follower, rather than to tighten the gland nuts.

If a pump is to operate under suction lift, both stuffing boxes should be liquid-sealed. The ¼ in. tapped openings over the packing are to be utilized for this purpose. Each opening should be piped through a valve to an external source of clear liquid free from sand or grit. In this way there will always be a small amount of clean cold water working both ways along the shaft sleeves which will prevent any abrasive liquids or corrosive fluids from working into the gland and injuring the packing. With the packing properly adjusted at 15 to 20 pounds, pressure greater than the pressure developed in the inside of the packing gland is sufficient for effective sealing. It is important to locate the metal cage or lantern rings properly when packing the pump so as to permit the free circulation of the water. The liquid seal is not required for operation under positive suction pressure.

In re-packing a pump it is always advisable to remove all of the packing, using hooks or cork screws inserted at points diametrically opposite to each other for best results. There are several types of packing hooks that can be used. One type that has proven satisfactory is a hook that is securely fastened to a flexible steel cable and furnished with a suitable handle so that these hooks can be used in very close glands where there is not sufficient room to use the ordinary type of hook. Care must be used in handling any type of hook as they are usually made of tempered tool steel and will score the softer bronze sleeves if not used properly. After the packing has been removed, if it is a good type of material, it can be cleaned, scraped and re-packed into the gland, adding new packing when necessary. The gland should be tightened uniformly on each side so as to compress the packing evenly and to insure against binding the shaft sleeve. The final adjustment can be made after the pump has been in operation a few minutes.

Too much emphasis cannot be laid on the importance of the proper selection of the packing used to suit the requirements of the work. For reciprocating rods working against steam or air pressures, usually the high-pressure types of packings are selected. These packings have a rubber impregnation which is acted upon by the heat encountered to vulcanize it into durable form, as it is on account of the rubber compound that the high pressure packings are limited to use on reciprocating rods and are not generally suitable for use on high speed rotary work. For extremely high speeds, ranging from 1,750 r.p.m. to 6,000 r.p.m., great care must be used in selecting and applying packings. On slower speeds the selection of packings is a much easier matter, but it may be said that any packing which is suitable for high speed would be ideal for low speed.

The flexible metallic packings are used extensively, and if applied to steel, cast iron, monel metal, or hard rods, plungers or shafts other than brass or bronze, will often give long periods of satisfactory service, provided they are installed on apparatus running in true alignment, and

on parts free from wear, scores, or shoulders. The flexible metallic packings should not be installed on high speed brass or soft bronze shafts, rods or plungers as the lead element is apt to amalgamate with the brass or bronze and produce rapid deterioration of the packing, or scoring or cutting of the shaft, rod or plunger surface. This does not happen on steel, cast iron, or other hard metals.

Because of the large variety of packings on the market which are suited for practically all packing requirements, it is often very advisable to consult with a representative of a reputable manufacturing company. These firms maintain a staff of competent, specially trained men of long experience in the packing field. They will gladly assist in any possible manner, in matters pertaining to packing problems.

CONTROL OF CHLORINATION *

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The treatment of the subject in this paper is an endeavor to present a fresh viewpoint which will serve as a sound basis for a reappraisal of sewage chlorination. An exhaustive consideration has not been attempted, but rather an outline around which discussion of all phases may center.

As a logical approach, it appears well to analyze the basic reasons for sewage chlorination. Sewage chlorination in its fullest meaning is increasingly regarded as covering the use not only of chlorine but of its derivative salts, largely ferrous and ferric chloride. Since the uses of chlorine and of its derivative salts are inter-related, and since their proper application follows along the same lines, all of these chemicals will be given consideration.

Consideration will first be given to the wide range of applicability as well as to the fundamental reactions of chlorine and its salts in the field of sewage disposal. This will more accurately indicate the requirements to be kept in mind when specifying sewage chlorination control equipment.

The actual practical uses of chlorine and its salts have been tabulated so frequently that their repetition is unnecessary. However, it would be well to point out that in view of the possibilities of these compounds, it is desirable to provide opportunities for at least periodical application of chlorine and its derivative products to various points in a treatment plant such as:

a. Influent.
b. Grease removal units.
c. Flocculators.

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d. Primary clarifiers.
e. Trickling filters.
f. Return activated sludge lines.
g. Effluent.
h. Sludge thickeners.
i. Supernatant return lines.

Again, instead of listing the actual uses of chlorine and its salts, a much more usable picture of the possibilities in chlorination can be built around an outline of the fundamental reactions in which chlorine plays a part in sewage treatment practice. Undoubtedly all of the past uses of chlorine, as well as the future uses of chlorine, can be grouped under several basic headings, and if these headings are clearly recognized, it will aid individual solution of particular problems not tackled to date.

The basic reactions employed in all sewage chlorination can be analyzed in terms of their true nature and in reference to the chlorine compound used. To W. J. O'Connell goes the credit for the new nomenclature used in this tabulation.

Simple chlorination is always used to effect—

I. *Sterilization: Oxidation*—which in practice may be for any one of the following specific purposes:

A. Destruction of pathogens (disinfection).
B. Destruction of sulfate splitters.
C. Destruction of acid formers.
D. Destruction of filamentous organisms (activated sludge bulking).
E. Destruction of organic coatings.
(1) Pipe slimes.
(2) Organisms on biological oxidation beds—trickling filters, Dunbar beds, slow sand filters.
F. Chlorination of grease.
G. Stabilization of organic matter (B.O.D. reduction).

Chlorine and either or both of its derivative iron salts can be used for:

II. *Reaction with Sulfides*—which in practice may be for—

A. Release of free sulfur.
B. Formation of ferrous sulfide.

Chlorine or its derivative trivalent iron salt can be used for—

III. *Electrolyzation of Colloids: Coagulation of Suspended Solids*—which in practice may be for—

A. Coagulation of finely dispersed suspended solids.
B. Chlorination of protein.
C. Formation of ferric hydroxide.
D. Formation of ferric jell in biological units.
E. Granulation of digesting and digested sludge.

If the basic concepts of the reactions of chlorine as outlined above are kept foremost in our minds, the list of uses in practice under each of the three major classifications for chlorine reactions will undoubtedly be enlarged in the light of expanding knowledge and through further research.

Before proceeding further it should be pointed out that the use of chlorine, "Scott-Darcey chlorination," and chlorine salts is not to be regarded as a process of sewage treatment in itself. Rather, it is to be considered as a very flexible tool to aid basically biological plants to take care of peak loads. Such peak loads may occur daily or seasonally. In California the large number of food packing and processing plants of various types possibly give us more than our share of peak industrial loads.

A review of the above fundamentals will determine which forms of chlorine or its derivative salts are required in each case. Usually a combination of them will be indicated. Also there will be a great many cases where the degree of need may not justify an adequate equipment installation to apply any one of the required chemicals, but where the combination of all needs will justify a proper installation of equipment to give an accurately controlled amount of chlorine or either of its derivative salts, applied to several points in the treatment plant. Such equipment is now available and has been included in the design for a number of projected treatment plants in this state. One cannot escape the conclusion that having available chlorine and its derivative products, arranged for multiple points of application, operators could quickly cure or eliminate many sewage plant headaches.

In the control of chlorination it is essential that sewage flow variations be taken into account and that the control of the application of chlorine and its compounds be regulated to compensate for changes in flow. This can be done manually by re-setting feed rates at regular intervals to follow flow changes, or flow-controlled automatic equipment can be installed. However, usually such regulation is only adequate for treated sewage of practically constant strength.

In all cases of raw or partially treated sewage it is equally important to take into account the variation in the strength of the sewage as well as in the quantity or flow. Under our average western conditions it is an unfortunate but inescapable fact that when the flow is the greatest the sewage is strongest so that the increase in the requirements for chlorine or its derivative compounds varies geometrically. Therefore, while a peak flow rate might be only double the average, the greater sewage strength at the time of peak flow will usually require four or more times the average chlorination capacity; on the other hand, the minimum requirements may approach or actually be zero for weak low night flows. As illustrative of the last point it is interesting to note that our old friend, T. R. Haseltine, now Superintendent of Sewerage, Butler, Pennsylvania, applies chlorine and its derivative salts (along with lime) from 7 A.M. to 10 P.M. only, relying on straight biological treatment to take care of the weak low night flows.

To take care of the geometrical variations of sewage strength plus the flow variations, compound, time-rated, automatic equipment is essential. Such equipment would take care of variations proportional to the flow, with increases in dosages in parts per million superimposed on the flow controlled variations; the time programmed superimposed variations would take care of the changes in strength of the sewage based upon studies of strength variations. Such equipment is under active consideration for several plants in this state.

In all probability another type of automatic sewage chlorination equipment will be available as a result of investigation now under way. Such equipment will vary the chlorine dosage in relation to the chlorine requirement, even though this requirement be affected by both changes in flow and changes in the strength or chemical composition of the sewage to be treated.

It is hoped that this discussion will aid in establishing a sound basis for the application of chlorine and its derivative salts, to the end that sewage treatment plants will have fewer "bugs" both literally and figuratively. Those engineers with whom the subject has been discussed have felt that the availability of such a many edged tool—that is, equipment for the proper application of chlorine and its salts to multiple points in the plant—will make it much easier for an operator to take the sewage as it comes and turn out consistently an effluent of the quality required. Similarly odor control and protection of plant structures and equipment will be greatly facilitated. As we all know, we can be sure that the sewage will come—both weak, medium and strong—and particularly strong at the most embarassing moments.

BIOLOGICAL INDICATORS OF INTENSITY OF STREAM POLLUTION *

By M. S. A. Campbell

Bacteriologist, Bureau of Sanitary Engineering, Indiana State Dept. Health, Indianapolis

The living indicators of the intensity of stream pollution include certain common and readily recognizable water plants and animals. They offer an accurate index to the oxygen content of a stream, which, in turn, measures the intensity of pollution.

It is a well established fact that organisms occur in, or are absent from, a given locality in proportion to the extent to which the surroundings are favorable or unfavorable to them. Each species or group of species has its individual set of requirements—a kind of food, a degree of temperature, a quality or quantity of air or water, a degree of light—which, if satisfied, permit success in growth and reproduction.

The existence of a definite relationship between the environment and the individual organisms living in it may be of value in many ways.

* Taken from Dec., 1938, issue of *Sewage Gas.*

For instance, when one is armed with the knowledge of physical, chemical, and biological factors constituting an environment, the kind of organisms which may occur can be predicted, and conversely, if this knowledge be lacking and the kind and requirements of the individual organism which occur are known, then the nature of the environment may be evaluated. It is this latter method which is used in stream pollution studies to determine the extent of contamination which exists in a given locality.

The addition of sewage to water is by general agreement said to "pollute" it, and organisms which can endure and exist under the changed conditions brought about by this pollution are logically called "pollutional forms." Those forms which occur naturally in the stream but disappear when the polluting materials are added are termed "clean-water forms."

When sewage is discharged into water a whole train of events is put into action. If the sewage is discharged into a lake the currents about the outfall are sluggish and shift their direction, these events take place in close proximity to each other, change their location and are not well defined. If on the other hand, the water is in motion, as in a stream, the events do not occur at one place but in a series of zones readily distinguishable below the point of pollution. These zones are not fixed but shift and are modified in character with the changing seasons and with varying hydrographic conditions. They are more accentuated in type during the warmer months and during low river stages than in winter or when the stream is in flood. In spite of this variability, the zonal differentiation is sufficiently marked at all times to establish its value in the diagnosis of the natural purification of streams.

In correlating distinguishable stages of pollution with their respective chemical and biological characteristics, the stream is divided into four zones, and designated by the terms "recent pollution," "active decomposition," "recovery," and finally "cleaner water." Analogous terms are applied to the characteristic organisms found in the respective waters. The following is a description of the chief organisms found in these zones (see diagram).

Zone of Recent Pollution.—This first zone is found below sewer outlets that carry organic wastes into water. In streams it occupies a relatively short stretch of water.

Where the sewage enters the stream, the water becomes turbid and gray in color. The suspended matter settles to the bottom and forms sludge deposits that decompose slowly.

At first the sewage discharged into the water is fresh and is often relished by fish, which, therefore, frequent the vicinity of the outfall. Decomposition as a result of bacterial activity soon begins; the bacterial population increases greatly and reduces the supply of dissolved oxygen; carbon dioxide increases.

As decomposition becomes established, the typical water fungi (water molds) appear. They form in dense masses, covering the

stones of the bottom and clinging to submerged sticks and plants. The newly developed forms are frequently white, but the older parts tend toward an olive green or "putty" gray color, turning to a rusty brown in the oldest portions. These fungi feed on, and disintegrate waste material and absorb oxygen. The fungi represented are chiefly *sphaerotilus natans*, the so-called sewage fungus, *leptomitus*, and *achlya*. These fungi or water molds, particularly if of colors other than green, indicate decreasing oxygen conditions.

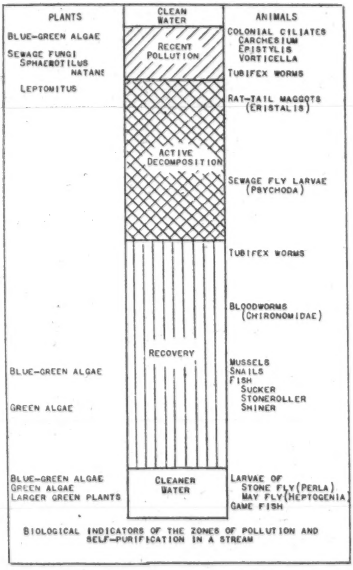


FIG. 1.

Mixed with the fungi, or forming growths of similar appearance, are colonial ciliates (microscopic one-celled animals). The frequent ciliates are *carchesium, epistylis,* and *vorticella.*

Green plants (pondweed (*potamogeton*), duckweed (*lemacea*), eelgrass (*vallisneria*), etc.) are found in this zone, the larger and more highly organized forms in the upper portion, giving place to smaller and lower forms in the lower portion, which finally disappear as the oxygen is used up and the lower limit is reached. Littoral (shore area) forms of green or blue-green algae (minute plants) cover submerged or frequently wetted stones or mud along the margins of the stream. Among the algae found here are *stigeoclonium* (green), *oscillatoria* (blue-green), and *ulothrix* (green).

Near the lower limit of this zone, small reddish tubifex worms (water earthworm or slime worm) appear, working the bottom sludge, made up of wastes and decomposing fungi. *Limnodrilus* (a form of water earthworm), is also a common species found in this habitat. *Tubifex* marks approximately the limit of fish life and the lower limit of the zone of "recent pollution."

It is apparent that this zone of recent pollution is a zone of degradation in which life is reduced from a highly organized to a more primitive state.

Zone of Active Decomposition.—This zone is a short one, occurring only in heavily polluted streams in which the dissolved oxygen is nearly or completely eliminated and aerobic organisms (with air) give way to anaerobes (without air). The characteristics of the upper and lower portion are very much alike although opposite in trend. The middle portion is truly septic, completely devoid of dissolved oxygen.

Bacteria continue to flourish in large numbers, anaerobic forms taking up the work of the aerobic organisms when the middle portion of the zone is reached. Protozoa (microscopic one-celled animals) and other animalcules follow a similar course to the bacteria, aerobic forms being succeeded by septic genera which are later followed again by aerobes.

Fungus life in its lowest forms is plentiful at the upper end of the zone, but disappear in the septic portion of the zone.

Green plants are absent except of the lower end of the zone.

Tubifex worms disappear in the upper end of the zone and reappear near the lower one. They are replaced by the larvae of the sewage fly (*psychoda alternata*) and the rat-tail maggot (*eristalis tenax*). Rat-tailed maggots are found throughout this zone, except perhaps in the most septic parts.

Fish may penetrate the upper and lower limits of this zone, but cannot live where conditions are the worst.

This zone is sometimes called "Septic Zone" or zone of greatest concentration of polluting substances.

Zone of Recovery.—The zone of recovery is directly opposite in its manifestations to the zone of recent pollution, and extends over much larger stretches.

Bacteria decrease in number as the available food stuffs are consumed. Protozoa, rotifera (transparent microscopic animals), and crustacea are present. Dissolved oxygen increases.

Fungi develop to a limited extent, blue-green and grass-green algae make their appearance in this order and diatoms are numerous toward the lower end. Larger aquatic plants reappear (pondweed (*potamogeton*), duckweed (*lemacea*), eelgrass (*vallisneria*), waterweed (*elodea*), etc.). Sponges and bryozoa (moss animals) are found attached to sticks, plants or pebbles.

There is usually an accumulation of brown rather than black sludge brought down from above. In this sludge, the blood-worm (midge larvae, chironomidae—brilliant red, worm-like, with fleshy legs or pro-

legs) typical of this zone, flourishes. They indicate recovery and conversion of wastes into fish food. *Tubifex* may be found burrowing in the mud at the upper end. Mussels, snails, and insect larvae develop in the bottom sludge.

Certain fish, such as the sucker, stone roller, creek chub and shiner, are found in this zone, growing fat on blood-worms and on the bottom sludge.

Zone of Cleaner Water.—Below the three zones of pollution and visible self-purification is found the cleaner water zone in which natural purification processes—physical, chemical, and biological—continue their beneficent work.

This zone is characterized largely by the normal flora and fauna of rivers. Green plants large and small predominate and are frequently of more highly organized types than those in the polluted sections. Microscopic forms consist chiefly of rotifers and crustaceans. The clean bottom is populated with the larvae of the stone fly (*perla*), may fly (*heptogenia*), dragon fly (*anax*), and caddisworm (*hydropsyche*). Mussels, snails (*campeloma*), and crayfish may be present. Game fish find conditions favorable for existence.

The first step in interpreting the results obtained in a pollution study, is to classify the organisms, as given above, with respect to their reaction to pollution.

EIGHT YEARS' EXPERIENCE IN IMHOFF TANK OPERATION *

By James Hastie

Superintendent of Sewers, Great Neck Village, Long Island

The sewage treatment plant of the Great Neck Sewer District is located on East Shore Road in Great Neck at the head of Manhasset Bay.

The sewage passes through a 1½-in. bar screen ahead of a reversible-flow Imhoff tank which has five flow compartments and four gas vents. A chlorinating station is located over a chlorine contact basin.

Sludge is removed from the tank onto glass-covered and open drying beds by means of air lift. Dried sludge is used on lawns and shrubbery about the plant and for filling low spots. The present flow through the tank is about 1,000,000 g.p.d. The sewage is entirely domestic except for the waste from one laundry.

The plant is designed to handle about 1.3 m.g.d. With a detention period of two hours the actual flowing-through time is somewhat less.

Operation of the Imhoff tank commenced in March, 1930. Digested sludge was pumped into the digestion compartments from the septic tanks of the old plant. The sludge was semi-digested and ill smelling.

* Presented at the Eighteenth Meeting of the Long Island Section of the New York State Sewage Works Association, The Antlers Hotel, Port Washington, Dec. 29, 1938.

Sewage was then turned into the tank and has been flowing through continuously except for a period of one month when a large amount of industrial oil clogged it up entirely. Initial operating routine included daily washing down of tank walls, gas vents and platforms. The entire structure was kept as clean as possible.

A chain drag was used to clean the slots once a week. No lime was necessary during the first year of operation as no foaming or unusual condition were noticed.

The flow through the tank was reversed every two weeks in order to load the digestion chamber uniformly. In August, 1930, the first sludge was drawn on to the drying beds. It was apparently a well digested sludge which dried fairly well.

Normal operation continued until the following spring when sludge drawn to drying beds was thin, had a bad smell and was slow drying.

Pitcher-type sampling pumps were then installed and it was found that there was very little digested sludge in the chamber. Too much sludge had been removed. No more sludge was drawn for several months until the necessary amount of digested sludge for seed had accumulated in the digestion compartments.

Because of this experience the sludge blanket has been kept at or near a point about 6 in. below the neutral zone. Sludge drawn under these conditions to date has been uniformly well digested and inoffensive.

The pH of sludge drawn has held between 6.6 and 6.8 all the time. Since the sludge has always appeared well digested and inoffensive, as far as odors were concerned, it has never been necessary to condition it with lime. While it is generally thought that a pH of 7.0 or higher is necessary to produce a good sludge it has not proven so at this plant. As a matter of fact the pH has held closer to 6.6 than 7.0 at all times. In 1935 an attempt was made to raise the pH to 7.0 by the addition of lime. Several hundred pounds were added to the sludge through the gas vents. No increase in pH was noticed so lime was discontinued.

On several occasions slight foaming took place in parts of the tank and this was corrected by changing the flow and drawing sludge. The foaming then ceased within a few days. There has at no time been excessive foaming except in June, 1936, when a large amount of industrial fuel oil was illegally discharged into the sewer and practically turned the Imhoff tank contents upside down. Sludge particles were coated with oil films and the whole tank was filled with an oil-sludge emulsion. Foaming was so bad it was utterly impossible to control it. Next it was necessary to empty the tank and remove the sludge and all deposits from the bottom.

The entire tank was thoroughly cleaned and sewage turned in again, following the same procedure as when the tank was originally started.

In order to keep the tank clean and the gas-vent scum broken down, large quantities of water were used. The writer felt that this quantity of cold water introduced into the tank might have some detrimental effect on the sludge in the digesting chambers. Incidentally, water costs were running high.

In 1937 a portable centrifugal pump was purchased and since then clarified sewage has been used in hosing down tank walls and gas vents. A considerable saving in labor has been effected. Before using this pump, three to four hours' work was necessary. Since using the pump about one hour is sufficient to do the same work and the general condition of gas vents has been very definitely improved.

Sludge is dried on glass-covered beds. The beds are composed of 6 in. washed sand on crushed stone.

The filtrate is returned to the inlet of the Imhoff tanks. Sludge has dried readily at all times. With favorable weather cracks in top surface have shown as early as 36 hours after filling.

Eight years of successful operation of the Great Neck Sewer District Imhoff tank have demonstrated that with ordinary domestic sewage no trouble need be expected if a reasonable amount of operating care is exercised; and that a quickly drying and inoffensive sludge may be produced with a pH considerably below the neutral point. I believe that cleanliness is of the utmost importance both in the tanks and around the plant.

BELGRAVE SEWER DISTRICT SEDIMENTATION AND SEPARATE SLUDGE DIGESTION *

By Herbert O. Johnson

Superintendent, Belgrave Sewer District

The Belgrave Sewer District is served by a primary treatment plant of the separate sludge digestion type. It consists of two mechanically cleaned rectangular, horizontal-flow sedimentation tanks, a chlorine contact chamber, a heated mechanically agitated digestion tank, a glass covered sludge drying bed, and a structure which includes sludge pump room, boiler room, chlorinator room, laboratory, garage and the district offices.

The tanks are designed to handle one m.g.d. and provide a detention period of approximately two hours. The present flow is approximately 3 m.g.d. and the theoretical detention is approximately 6 hours—the flowing-through period, however, is considerably less. The character of the sewage is that of domestic sewage, with very little industrial wastes. The average of the analyses made on catch samples taken at the time of peak flow shows an average suspended solids content of 185 p.p.m. The volume variation of the flow is considerable, since the area served is a commuter community and the entire flow runs to the plant by gravity. The solids concentration has been bound to fluctuate between 8 p.p.m. at 6 A.M. to an average high of 225 p.p.m. between 10 A.M. and 1 P.M., with sporadic results running as high as 400 p.p.m.

The sludge scrapers in the sedimentation tanks are of the crane type and in traversing the length of the tank carry the sludge to a hopper at the influent end. On the return trip a skimmer pushes floating mat-

* Presented at the Eighteenth Meeting of the Long Island Section of the New York State Sewage Works Association, The Antlers Hotel, Port Washington, Dec. 29, 1938.

ter to a scum drain near the effluent weir which also acts as a baffle. Suspended solids removal has averaged 61 per cent and settleable solids removal 97 per cent. Suspended solids in the effluent averaged 74 p.p.m.

Raw sludge is removed from the tanks twice daily by means of piston-type sludge pumps. In general a fixed amount of pumping is done in the morning and the sedimentation tank hoppers are cleaned of sludge in the afternoon. The sludge scrapers are operated from noon until pumping is finished. Approximately 275 cu. ft. of sludge is removed daily which has had an average solid content of 4.2 per cent, of which 60.8 per cent is volatile matter. Raw sludge samples for analysis are composited over a pumping period. Scum is allowed to accumulate for several days, depending on the temperature and humidity, and is then pumped into the digester. Operation in this manner has resulted in clean tanks free of offensive odors or appearances at all times. Deviation from this procedure results in a blanket of sludge and scum forming over the tank surfaces and large amounts of raw sludge rising from the hopper. This, of course, increases the solids escaping with the effluent.

Sewage passes from the tanks into a chlorine contact chamber where it receives a dose of chlorine sufficient to maintain a residual at all times of about 1 p.p.m. This requires a feed at the rate of 40 lb. per 24 hours up to 6:00 P.M. and 32 lb. per 24 hr. for the balance of the day. Some work was done on chlorine demand of the tank effluent which indicated a demand varying from 4 to 18 p.p.m.

Chlorine is fed by two vacuum type, manual control W. & T. chlorinators hooked up so that either post-chlorination, pre-chlorination or split chlorination may be used. Because of the fresh character of the sewage, pre-chlorination has not been required to date.

Raw solids are pumped into a 30 by 15 ft. fixed-cover digester. The temperature of this tank has averaged 88 deg. F. for the past two years and has been as high as 96 degrees. Summer temperature averages 93° and winter temperature about 85° F. The contents of the tank are agitated during the day by a mechanical stirring device. The quantity of digested sludge kept in the tank is calculated to be sufficient to properly seed the daily increment of raw sludge. The pH will vary between 6.8 and 7.1 but no addition of alkali is necessary either to raise the pH or to promote digestion. The addition of raw solids results in the displacement of an equal volume of supernatant liquor. This is usually quite clear, averaging about 0.2 per cent of suspended matter. A cloudy or heavy supernatant is generally an indication that the amount of digested sludge in the tank is too great, and some should be removed. At present there is about 3 cu. ft. of tank capacity per capita. No unusual operating problems have been encountered although they may be expected as the per capita capacity decreases.

Gas is collected in a dome on the digester and passes through measuring and protective devices. It is used under a boiler, which heats water for circulation through a coil in the digester, and also supplies hot water for the headhouse and for the laboratory.

Sufficient gas is generated for these uses and a considerable quantity is burned in a waste-gas burner. Gas production has been uniformly high, averaging 3900 cu. ft. per day, or approximately 1.3 cu. ft. per capita; of this amount 3000 ft. per day is burned in the boiler. Gas production figures out to be approximately 9 cu. ft. per lb. of volatile matter added to the digester.

When an excess of digested sludge has accumulated it is removed by pumping. There are many factors entering into determining the time and amount of pumping. Several different procedures have been tried and if other conditions permit, the best practice is to pump a small quantity at frequent intervals. We now pump about 300 cu. ft. every three or five days until a proper amount of seed remains in the tank.

The average volume of sludge removed is approximately 1500 cu. ft. per month, containing 9.1 per cent solids. This figures to be about 910 lb. of dry solids per m.g. Volatile matter averaged 42.5 per cent. After the hurricane the volatiles dropped sharply due to sand washed down.

Digested sludge is pumped onto sand beds protected by a standard glassover. The pumping procedure outlined previously fits in very nicely with the operation of the beds. A well dried and innocuous sludge is usually obtained in 9 to 15 days. Inclement weather has lengthened this to as much as 31 days. Sludge is allowed to dry to an average solids content of 44.7 per cent. Removal could be effected before this stage is reached, but is not yet necessary. Dried sludge of this solids content is light and easily handled. Sludge is disposed of in a dump on the plant site. There is some call for it by neighbors, and a fair quantity is used as mulch around trees by a nearby village, but the greater part goes to the dump.

Mechanical problems have been confined to replacement of mercoid switches, repacking sludge pumps, overhauling of gas meters, and minor electrical troubles. An oil pan was installed under the worm wheel of the digester so that the worm is continuously oiled. Previously grease of a special consistency was applied at intervals during the day.

Sampling procedures have been carefully worked out and routine analyses are made on samples taken under similar conditions so that results may be truly comparative. Sludge samples are composited and sewage samples are catch samples. Raw sewage is sampled at 10:00 A.M. or peak-flow time. Effluent is sampled between 12 noon and 1:00 P.M. It has been found that a tremendous amount of time can be spent in the laboratory but that routine analyses can be fitted in nicely with other plant work.

Plant operation has been relatively simple for the past three years and is attributed in part to the low flow of about 30 per cent of the designed capacity of the plant. As the flow increases it is to be expected that operating problems will arise which will require different operating procedures.

GADGET DIVISION

First Prize

Gadget Contest at the Neenah-Menasha Meeting of the Central States Sewage Works Association, Oct. 20, 1938

This gadget was more than a gadget and would be classed as an apparatus. It was Don E. Bloodgood's apparatus for determining the rate of oxygen utilization by activated sludge. This apparatus is described by him in the paper which he presented at the above meeting, published on page 927, Vol. 10 (November, 1938) of *This Journal* The cost is very small compared to well known apparatus on the market, and is said to be more accurate.

Second Prize

Neenah-Menasha Meeting of the Central States Sewage Works Association

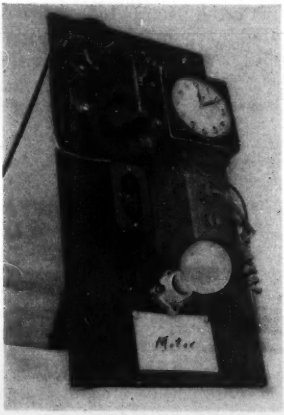
AUTOMATIC TIMING GADGET FOR SLUDGE PUMPS

By D. E. Bloodgood

Indianapolis, Ind.

It is not always possible to have a meter for recording the discharge of pumps. Even when the flow is determined by an indicating meter of some type, the measurement of the pumping time is difficult to determine accurately.

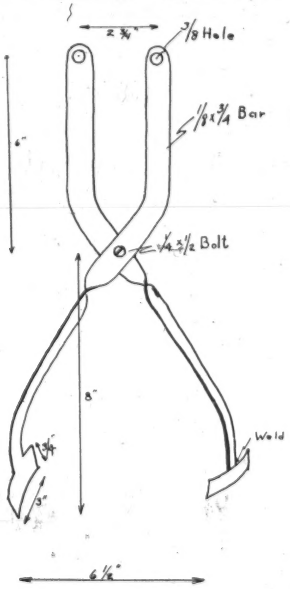
With an electric clock which will start and stop with the turning on and off of the electric current, it is possible to get the clock to operate only during the time that the pump motor is running. All that needs to be done to accomplish this, is to bring to the magnetic starting box of the motor a 110-volt circuit which is closed and opened by an extra set of contacts which are attached to the magnetic switch arm and are actuated by the magnetic switch in the pump motor circuit. See cut below.



THIRD PRIZE

NEENAH-MENASHA MEETING OF THE CENTRAL STATES SEWAGE WORKS ASSOCIATION

Rubber ball valves may easily be removed from the valve chambers by this "Sludge Pump Ball Remover" of C. O. Baetz, Supt. Appleton, Wis.

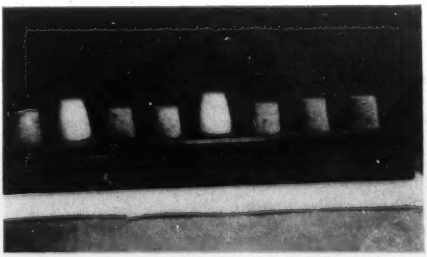


CRUCIBLE HOLDER

BY J. L. HENDRICKS

Operator, Sewage Treatment Works, Nashville, Illinois

In order to prevent breakage, extra Gooch crucibles are inverted over a row of properly sized corks attached to a block of wood.

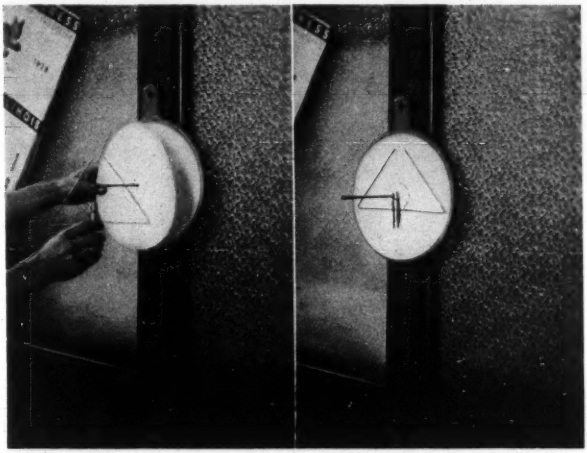


FILING RACK OF RECORD CHARTS

By E. A. Huffer

Illinois Department of Public Health, Springfield, Illinois

This rack (see picture) provides a means of filing used recorder charts. It consists of a circular piece of wood with a handle on the side, and a rod, the lower end of which is threaded, held perpendicular to the center of the face by nuts countersunk in both sides. A spring clothespin, fastened to a triangular shaped piece of stiff wire, is clamped onto the steel rod to hold the charts in place. This piece keeps the charts from curling.



TURBIDIMETER

By E. Hurwitz

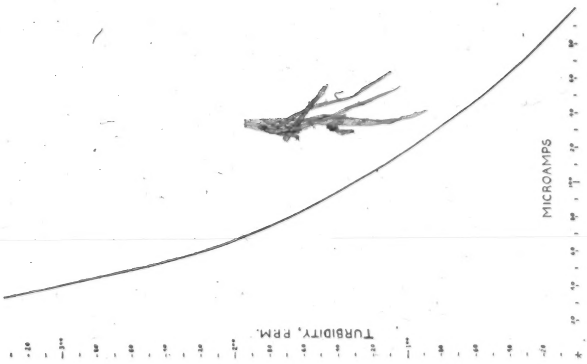
Principal Sanitary Chemist, The Sanitary District of Chicago

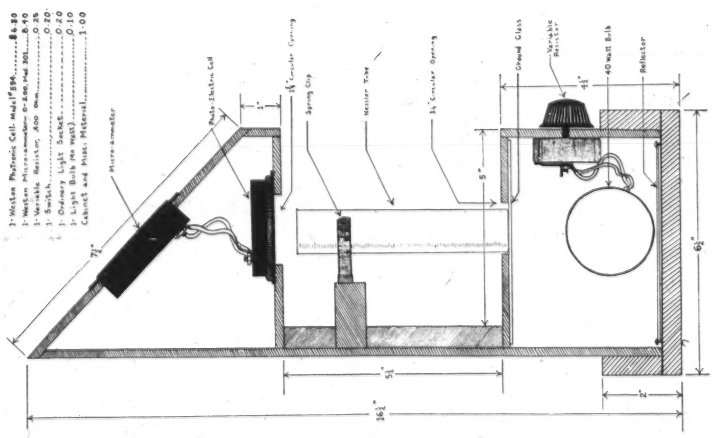
This instrument makes use of a fixed light source reacting upon a photo-electric cell through a fixed liquid column. The current generated records on a micro-ammeter. The micro-ammeter is calibrated against a Jackson turbidimeter. Turbidity readings are simplified and personal error is eliminated.

Use.

Adjust light intensity with variable resistor so that a column of distilled water (tube filled to mark) reads 200 micro-amps (= zero turbidity). Proceed to determine turbidity of samples by filling tube to mark, noting micro-ammeter reading and taking turbidity reading in p.p.m. from the graph.

An instrument intended for use only in determining turbidity may be calibrated to read directly in p.p.m.


MICROAMPS
TURBIDITY, P.P.M.


1-Weston Photronic Cell. Model #594.....$6.80
1-Weston Micro-ammeter 0-200, Mod. 301.....8.40
1-Variable Resistor, .400 Ohm.....0.25
1-Switch.....0.20
1-Ordinary Light Socket.....0.20
1-Light Bulb (40 Watt).....0.10
Cabinet and Misc. Material.....1.00
Micro-ammeter
Photo-Electric Cell
1"
1⅛" Circular Opening
Spring Clip
Nessler Tube
1¼" Circular Opening
Ground Glass
Variable Resistor
4½"
40 Watt Bulb
Reflector
7½"
5"
6½"
5¼"
2"
16½"

Editorial

INTERNATIONAL RELATIONS IN SEWAGE DISPOSAL

The chaotic state of international political relations is in marked contrast to the tolerance and mutual esteem of technical workers in the field of sewage disposal. This contrast is not unique for this particular branch of science, for amicable relations are also maintained between various nations and peoples in the basic sciences, in art, and in music, but the problems of sewage treatment and disposal seem to be of sufficient universal interest to transcend the intolerance and suspicion of international political relations. It is to the credit of the mentality and humanity of chemists and engineers that they maintain respect and admiration for progress in distant lands, even though such progress may develop along divergent paths.

These thoughts are prompted by the international character of the contributions to the Federation's Anniversary Book, "Modern Sewage Disposal," and also after perusal of two large books on sewage disposal recently written by foreign visitors to the United States. These visitors were: Mr. H. J. N. Hodgson, of Adelaide, South Australia; and a delegation of chemists and engineers from Argentina headed by Engineer Carlos J. Forn, member of the National Board of Health of Argentina ("Obras Sanitarias de la Nacion").

In the American Federation's new book, chapters were contributed by Dr. Imhoff and Dr. Heilmann for Germany; Dr. Calvert and Dr. Garner for England; Dr. Kessener for Holland; and Dr. Wilson and Mr. Hamlin for South Africa. Limitations of the scope and size of the book prevented further extension of its international aspects, but the contributions of these world-famous experts provide a comprehensive review of developments in sewage disposal in three of the most progressive nations in Europe, and in South Africa, where unusual geographic and climatic conditions have evolved unique types of sewage treatment works.

The Australian and Argentinean contacts are somewhat different. Mr. Hodgson was sent to the United States and Europe by his government of South Australia, in cooperation with the Commonwealth Fund of New York, to make an "enquiry . . . into the methods of Treatment of Sewage and Trade Wastes and matters related thereto in America, Great Britain, Holland and Germany." And what an enquiry he made! His report, "Sewage and Trade Waste Treatment," is a book of 534 pages, in which he has included more observations, data, and reviews of literature than can be found in any similar one-man report on record in the field of sewage disposal. The book was received in the United States in January, 1939, and covers the year of Mr. Hodgson's trip, from the fall of 1936 to September, 1937.

Mr. Hodgson travelled around the States so unobtrusively that we did not realize how thoroughly and how competently he was absorbing the important and significant details in American practice in sewage treatment. His obser-

vations are accurate and his conclusions logical. He compares practice in various countries, and selects what seems best. In general, he inclines toward American practice, although he prefers the English design of small settling tanks and longitudinal ridge-and-furrow aeration tanks.

The report by Mr. Hodgson includes valuable information on disposal of industrial wastes, administrative aspects of sewage disposal, and trends of sewage treatment in the four countries visited.

Mr. Hodgson was well-fitted for this trip as he had designed and operated a very interesting activated sludge plant at Glenelg, South Australia, prior to his departure. However, few men could have assembled such a comprehensive, unique and tolerant report, even with the benefit of experience in the field of sewage treatment. Samuel Johnson said—"He who would bring home the wealth of the Indies must carry the wealth of the Indies with him. So it is in travelling; a man must carry knowledge with him, if he would bring home knowledge." Mr. Hodgson brought knowledge, an open mind, and good judgment.

The delegation from Argentina was also a messenger of good-will from the southern hemisphere. Under Engineer Forn were two men interested in water purification, Chemist Dr. Daniel J. Bengolea and Engineer Arturo A. Barbeito; and two interested in sewage treatment, Chemist Dr. Ricardo A. Gaibrois and Engineer Carlos F. Daireaux. They arrived in New York in January, 1937, and attended the meeting of the American Society of Civil Engineers on Jan. 20, 1937. Then they travelled to many cities (26 for water and 41 for sewage) during the year, but spent most of their time in Chicago. In consequence, much of their report of 576 pages refers to Chicago plants and experiments. However, their conclusions are based on consideration of all plants visited, and their recommendations reflect the perspective they gained during their stay in the United States. They recommend a comprehensive series of experimental studies by the "Obras Sanitarias," based on the American practice of working-scale testing stations. Dr. Gaibrois has just been appointed to direct the chemical work of the O. S. N. We may expect interesting results from his work.

These international contacts are invaluable for both visitor and host. They help us to see ourselves as others see us, and they help our visitors to become acquainted with the great advances we have made in the theory and practice of sewage disposal. It is unfortunate that the Australian and Argentinean reports cannot be widely distributed in this country. However, we hope the Federation volume, "Modern Sewage Disposal," will receive wide distribution in these and other countries, to promote international respect and fellowship in a world that sorely needs it.

F. W. M.

Proceedings of Local Associations

SOUTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

Fourth Annual Meeting

Watertown, South Dakota, September 19–20, 1938

The Fourth Annual Meeting of the South Dakota Water and Sewage Works Conference was called to order at 10:00 A.M. Monday, September 19th, by President Rhea Rees. After the address of welcome by Hon. J. E. Low, Mayor of the City of Watertown, the following papers were presented dealing with sewage treatment.

Some Preliminary Experiences with a Small Digester Gas Engine, by J. E. Holst, Chemist, Water and Sewer Department, Mitchell, South Dakota. *Trends in Sewage Treatment,* by A. H. Wieters, State Sanitary Engineer, Des Moines, Iowa. *Stream Pollution,* by M. D. Hollis, State Sanitary Engineer, Bismarck, North Dakota.

A Dutch lunch was served at noon through the courtesy of the city of Watertown. The annual banquet was held in the evening in the Hotel Lincoln at which time the report of the committee on licensing and certifying water and sewage works operators was given. Briefly, the recommendations of this committee were to place the certification of such personnel on a voluntary basis. Under the program recommended, the Executive Committee would appoint an examining board to consist of three members; one the secretary of the conference, one a sewage treatment plant operator, and one a water treatment plant operator. The certificates to be issued would cover three classes of operators for both water and sewage plants. No person would be issued a certificate without examination.

Briefly, the qualifications necessary for the three classes of sewage works operators are as follows:

Class A. The applicant shall have had training and experience qualifying him to operate a plant employing the processes of the incineration of sludge, chemical treatment and mechanical dewatering of sludge or activated sludge, and to supervise the laboratory procedures necessary for controlling all such processes of treatment.

Class B. The applicant shall have had training and experience qualifying him to operate the sewage treatment plant using separate sludge digestion tanks, collection and utilization or biological oxidation other than activated sludge.

Class C. The applicant shall have had training and experience qualifying him to operate a sewage treatment plant having the more

simple processes of primary treatment such as Imhoff tanks or septic tanks.

At the business meeting on the second day the matter was further discussed and a motion made that the report of this committee be adopted and the Executive Council instructed to appoint an examining board as recommended.

Other matters of business discussed during the business meeting included the need of legislation permitting those municipalities so desiring to finance sewage treatment on a sewer rental basis. After considerable discussion the motion was made and consequently carried instructing the incoming president to appoint a legislative committee to prepare a suitable law to be presented at the next session of the legislature which will convene in January, 1939.

The following officers were elected for the coming year:

E. H. Schultz, Watertown, *President,*
C. R. Price, Rapid City, *Vice President,*
W. W. Towne, Pierre, *Secretary-Treasurer.*

Board of Directors—

A. J. Campbell, Chamberlain,
Glen H. Crafts, Hot Springs,
S. C. Berry, Lead,
G. J. Gunderson, Madison,
J. E. Holst, Mitchell.
Geo. Urbe, Mobridge.
E. R. Myron, Vermillion.

Incoming President Schulz appointed the following on the legislative committee:

R. E. Bragstad, City Engineer, Sioux Falls, *Chairman,*
Dow I. Sears, City Engineer, Huron,
J. E. Holst, Superintendent Water and Sewers, Mitchell.

Following the adjournment of the business meeting the Executive Council met and appointed the following as the board of examiners for certifying water and sewage works operators:

E. R. Matthews, Chemist Water Department, Aberdeen,
J. E. Holst, Superintendent Water and Sewers, Mitchell,
W. W. Towne, State Sanitary Engineer, Pierre.

On the afternoon of the second day an inspection trip was made to the Watertown water and sewage treatment plants. At the water plant the group viewed the experiments which were being conducted in using bentonite as a coagulant in the water treatment process. Mr. Schulz stated that the results so far on a plant size scale indicated that this material might be used without any deterioration in the quality of water, delivered, and at the same time effecting some considerable saving in the cost of chemicals.

The meeting adjourned followed the completion of the inspection trip.

W. W. Towne, *Secretary*

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

Tenth Annual Convention

Minot, North Dakota, September 26–27, 1938

The 1938 Convention of the North Dakota Water and Sewage Works Conference at Minot, North Dakota, September 26–27, marked the tenth anniversary of the organization. This year's meeting was the largest the Conference has seen and also the most representative from the standpoint of membership cross-section. Water and sewage works operators and commissioners, city engineers, mayors, consulting engineers, commercial men, and representatives from South Dakota and Canada joined in a two-day discussion of their mutual problems. Registered for the convention were 129 delegates. In an effort to get closer to the individual municipal problems, more time was given to open forum and question box sessions.

The Conference adopted resolutions urging the inclusion of water and sewage works employees in municipal civil service employees in municipal civil service systems; endorsing the Missouri River Diversion Project; and commending the Federal Works Agencies in the state for their cooperation in effecting needed sanitary improvements.

The annual stag dinner and banquet climaxed the first day of the convention; a tour of Minot's water and sewage works followed by a Dutch Lunch at the water works closed the second day's session.

Officers elected for 1939 are: William Yegen, Superintendent of Waterworks, Bismarck, North Dakota, *President;* R. M. Jensen, Superintendent of Waterworks, Grand Forks, North Dakota, *Vice-President;* and M. D. Hollis, State Sanitary Engineer, Bismarck, North Dakota, reelected *Secretary-Treasurer.*

An important development during the Conference year was the absorption of the North Dakota Engineering Society by the Conference. The Engineering Society voted to disband their organization and merge with the Water and Sewage Works Conference; a substantial treasury balance was also transferred. The action of the Engineering Society was a splendid expression of their confidence in the Conference.

Displays and demonstrations were provided by the Flox Company, Layne-Western Company, Hersey Meter Company, Crane Company, and the Sanitary Engineering Division of the State Health Department.

Among the papers presented during the conference sessions were the following:

Financing Water and Sewerage Systems, Myron H. Atkinson, Secretary, League of North Dakota Municipalities, Bismarck. Three general methods and their limitations and advantages were discussed:

(1) General Obligation Bonds—A five per cent limitation based on assessed, not actual valuation. This method is generally disadvantageous for smaller municipalities because of the large vote required (two-thirds) and because of too small an assessed valuation. The interest rate is low.

(2) Special Improvement Warrants—An additional four per cent over five per cent general limitation may be issued for water and sewage works. Sale of these warrants is generally poor. Even in cases where WPA or PWA is furnishing forty per cent to fifty per cent of the cost of improvements, the investor generally requires a one hundred per cent levy before he will purchase these warrants. If these warrants are defaulted they revert to a general municipal obligation.

(3) Revenue Bonds—This method is a recent favorite because of the protection to the investor, especially in cases where federal aid is employed. These bonds constitute a mortgage on the utility, and in cases of federal assistance, the utility is generally bonded for only a percentage of its value, the balance being supplied by a federal agency. A total of twelve per cent may be levied for water and sewage works. The combination of general obligation bond and special district bond is probably most commonly used. The surplus earnings of the utility are put into a sinking fund to retire general bonds. These general bonds carry a lower rate of interest.

Multiple Benefits from Stream Gaging, E. F. Chandler, Dean, Civil Engineering School, University of North Dakota.

In surveying North Dakota water needs, Dean Chandler pointed out that a daily rainfall of only one twenty-thousandth of an inch would be equivalent to the domestic and industrial needs of the people, based on a per capita consumption of one hundred gallons per day. The use of and need for gaging records, with special reference to municipal water supply and sewage disposal, and a summary of gaging activity and methods of measuring stream flows were presented. According to Dean Chandler, it is more important to have fairly accurate continuous flow records over a long period of time than accurate records for a shorter period. Fluctuations in average yearly flows of as much as one hundred times were cited.

Ground water resources were reviewed and it was brought out that with depletion equaling repletion, the artesian supply in the state is approximately equal to consumption needs, again based on a per capita use of one hundred gallons per day.

M. D. Hollis, *Secretary*

GEORGIA WATER AND SEWAGE ASSOCIATION

Seventh Annual Water and Sewage School

Georgia School of Technology

During the four day session of the Annual Georgia Water and Sewage School at Georgia Tech, November 16, through 19, a new record

for attendance was established. An official registration of 233 was recorded with an estimated attendance of 240 being reported at this training season which is jointly sponsored by the Georgia Department of Public Health, the Georgia School of Technology, and the Georgia Water and Sewage Association.

Of those attending the school quite a number stood examinations for operators certificates. There were 9 for Class A, 14 for Class B, and 22 for Class C.

The operators were officially welcomed by Dr. M. L. Brittain, President, Georgia School of Technology, and Dr. T. F. Abercrombie, Director, Georgia Department of Public Health, Wednesday morning. Mr. Lewis Simonton, President of the Georgia Water and Sewage Association, responded to the welcome.

An outline of the course for the School and a discussion of progress in Georgia relative to water supply and sewage treatment problems was presented by W. H. Weir, Georgia Department of Public Health. In an interesting discussion on water quality, the ultimate price paid and possible hazard which may result from indifference to this all important matter was pointed out by N. M. deJarnette, of Georgia Department of Public Health.

For the Wednesday afternoon session, three groups were established. The Basic Water Group under Professor Wyckoff, Prof. of Biology Department, Georgia Tech, W. H. Weir, Georgia Department of Public Health, and N. M. deJarnette, Georgia Department of Public Health, covered the essentials of water purification while the Advanced Water Group under Dr. H. B. Friedman, Chemistry Department, Georgia Tech, and W. L. Avrett, Georgia Department of Public Health, were given lectures and demonstrations relative to the chemistry of water treatment. The Sewage Group was given a demonstration by G. R. Frith, Georgia Department of Public Health, at the Atlanta Clayton Sewage Treatment Plant, and apparatus was arranged for those so desiring, to participate in actual laboratory work.

The general session Thursday morning was led by Clark W. Jones, Supt. of Water Works, Dalton, on the subject of distribution systems with each phase being discussed by capable men in this field.

The Association Banquet was the climax of the meeting as far as good fellowship and the spirit of the Georgia Water and Sewage Association is concerned. The sponsor for the occasion was the Paper Makers Chemical Division, Hercules Powder Company.

At the business meeting immediately following dinner, the new officers for the coming year were elected. Lloyd Jacobs, Asst. Superintendent, Newnan Water and Light Dept., Newnan, was elected *President,* and the other officers chosen were, Clark Jones, Superintendent, Dalton, first *Vice-President;* L. D. Cannon, Pools Manager, Warm Springs Foundation, *Second Vice-President;* and Paul Weir, Superintendent of Filtration, City of Atlanta, was re-elected *Secretary-Treasurer.* The Frederick J. MacMullin Memorial Award was presented to Carl Alexander, Superintendent of Filtration, Rome. The

Association Awards for meritorious service were presented to Sherman Russell, Operator, City of Atlanta; E. P. Woodall, Supt. of Water Works, Blackshear; and J. M. George, Supt. of Water Works, Thomaston.

The chair was turned over to the new president by Lewis Simonton, the retiring president and following the speech of acceptance, the secretary announced the committees for the present year.

Of the important matters of business carried out, the changing the name of the Association to Georgia Water and Sewage Association was one of the most noteworthy. In the true toastmater style the out-of-state visitors were introduced to the gathering by W. H. Weir, Georgia Department of Public Health, Atlanta.

An honorary Class A Certificate was presented to W. H. Weir, in appreciation of his untiring work as founder of the Georgia Water and Sewage School and as advisor to the Georgia Water and Sewage Association.

From this point on the crowd was completely but pleasantly mystified by Mr. Julian Boehm of Atlanta with his variety of magic tricks. As a true amateur magician, Mr. Boehm gave us a performance far surpassing the professionals in genuineness, which was enjoyed by all.

The Sewage Group returned to the Clayton Plant Friday morning to complete their work of Wednesday.

The Fish Fry at the Atlanta Water Works Shops was "top notch," and the display of equipment and gadgets as presented by Mr. W. M. Rapp and his assistants, will be remembered quite a while by those who had the privilege of seeing it.

Following the Fish Fry in the afternoon examinations for operators certificates were given. The number participating was given previously. Friday night there was a lecture and moving picture on the subject of "Plumbing and Cross-connections," presented by Mr. E. L. Penfrase, Research Engineer, New York City.

Saturday morning the Members of the School had the privilege of inspecting the Atlanta Water Works and the Clayton Sewage Treatment Plant.

Inspection of the new Clayton Sewage Treatment Plant gave the members an idea of just how a large plant capable of handling approximately 42 million gallons of sewage daily is operated.

Through the courtesy of Georgia Tech officials, those attending the School received complimentary tickets for the Florida-Georgia Tech football game.

It may well be said the Georgia Water and Sewage School has passed the seventh milestone with the true purpose of its founders and members accomplished to as marked a degree as is humanly possible in such an organized body gathered for the purpose of increasing their knowledge of a subject. We hope that those who could not attend this year will maintain their membership and interest in the Georgia Water and Sewage Association and make it a point to attend the Georgia Water and Sewage School in 1939.

The Georgia Water Works and Sewage Operators Association no longer exists. We now have instead: *The Georgia Water and Sewage Association.* Seven years ago when the Association was organized with a comparatively small group of operators there was possibly a need for the large and formidable name. However, the recognized merit of the organization has caused it to grow by leaps and bounds to a point where the Association itself commands great respect and, hence, has no more use for the long impressive name. In recognition of this fact the name was changed at the business meeting held during the last Short School. If the membership and prestige continue to grow perhaps we will later be able to designate the Association simply as the G. W. and S. A.

PAUL WEIR, *Secretary*

NEW YORK STATE SEWAGE WORKS ASSOCIATION

Eleventh Annual Meeting

New York City, January 19–21, 1939

The Eleventh Annual Meeting of the New York State Sewage Works Association was held in New York City, January 19 to 21, 1939 with headquarters at the Hotel McAlpin. Over 300 members and guests were registered.

Rodney E. Cook of Riverhead, Channel Samson of Kenmore and Herbert H. Wagenhals of Syracuse were elected to the Executive Committee for a period of three years. Mr. Newell L. Nussbaumer of Buffalo, was elected *President* and Mr. C. George Andersen of Rockville Centre, *Vice-President.* A. S. Bedell of the State Department of Health, Albany, was reappointed *Secretary-Treasurer,* and J. C. Brigham of Albany was reappointed *Assistant Treasurer* for the ensuing year.

The program was arranged so that the members of the Sewage Works Association were able to attend all the Thursday sessions of the Sanitary Engineering Division of the A. S. C. E. In like manner the members of the A. S. C. E. attended the technical sessions of the N. Y. S. S. W. A. on Friday and the joint inspection trip on Saturday.

An added feature was the opportunity to attend the monthly evening meeting of the sanitary group of the A. S. M. E. on Wednesday, January 18th, the topic of the meeting being "Gas Engines for Operation of Sewage Gas."

Following the technical sessions of the A. S. C. E. on Thursday, the two groups gathered for the joint dinner, at which Colonel Donald H. Sawyer, President-Elect of the A. S. C. E. gave a very stimulating talk.

At the general business meeting on Friday it was noted that the association now had a membership of over 600 and that the Executive Committee had approved the formation of the "Western Section," making a total of three local sections in the State.

Resolutions were unanimously adopted expressing appreciation of the cooperation extended by the two federal agencies—P.W.A. and W.P.A.—in the successful development of sewage works projects and urging that this work continue to receive their favorable consideration.

At the technical session on Friday morning Dr. James A. Tobey's paper on "Legal Aspects of Stream Pollution" aroused considerable interest although time did not permit much discussion.

At the luncheon Charles C. Agar of Albany, N. Y., was presented with the Kenneth Allen Memorial Award for 1938 for the most meritorious paper of a technical and research nature. Following this, keys bearing the emblem of the association were presented to past presidents, the retiring president and the secretary-treasurer.

Great interest was shown in the afternoon session in the symposium on "Sewer Rentals," for which there were four prepared papers presented by R. C. Sweeney, Albany, N. Y., M. W. Tatlock, Dayton, Ohio, R. A. Allton, Columbus, Ohio, and W. F. Tempest, Chicago, Ill.

Wellington Donaldson of the Department of Public Works, New York City, presented a paper on "First Year's Operation of Wards Island Sewage Treatment Plant," and in preparation for the inspection trip on Saturday Messrs. Henry Liebmann and E. J. Fort presented a paper on "Features of the Tallmans Island Sewage Treatment Works, New York City."

On Saturday a joint inspection trip in five busses was enjoyed by 200 persons to the Tallmans Island Sewage Treatment Plant of New York City and to the World's Fair Grounds where luncheon was served in the cafeteria.

The spring meeting of the Association will be held in Albany, probably June 9 and 10, 1939.

A. S. Bedell, *Secretary*,
N. Y. S. S. W. A., State Department of Health,
Albany, New York.

Reviews and Abstracts

H. W. STREETER

THE PURIFICATION OF SEWAGE ON COVERED FILTERS

BY J. HURLEY AND M. LOVETT

The Surveyor, **94**, 605–607 (November 25, 1938)

Experimental work on the treatment of sewage by means of covered trickling filters with forced aeration has been carried on at the Barnhurst treatment plant of the Wolverhampton (England) Corporation. Two enclosed aerated filters, each 20 ft. in diameter, were built and filled with a hard basalt as filtering medium. No. 1 is a deep filter containing relatively fine media and intended to give complete treatment to settled sewage. No. 2 is a relatively shallow bed of coarser material, intended to give partial treatment to settled sewage at a very high rate. Both filters are dosed by revolving distributors, and air is supplied by two electrically driven fans with nominal capacities of 200 and 600 c.f.m. for Filters 1 and 2, respectively.

The stone in the filters is graded as follows:

No. 1 Filter:	1 ft. depth, 1½ to 2 in. (at bottom).
	11 ft. depth, ¾ to 1 in.
	1 ft. depth, 1½ to 2 in. (at top).
No. 2 Filter:	1 ft. depth, 2 to 2½ in. (at bottom).
	4 ft. depth, 1 to 1½ in.
	1 ft. depth, 2 to 2½ in. (at top).

Operating Results.—No. 1 Filter. Considerable trouble was experienced in obtaining rotation of the distributor at the low rates used in starting the filter. From the tenth to the eighteenth week the dosage was gradually increased from 133 to 169 gal. per cu. yd. per day. Ponding developed to a serious extent; therefore the dosage was reduced to 147 gal. per cu. yd. per day and the air supply increased for a period of two weeks. By this time all signs of ponding had decreased. Then the dosage was again gradually stepped up to 167 gal. per cu. yd. per day. Removals of more than 25 per cent of the ammonia nitrogen, 70 per cent of the albuminoid nitrogen, 85 per cent of the 4-hour oxygen absorption and 95 per cent of the 5-day B.O.D. were obtained.

For six weeks the filter was operated without forced ventilation, but there was some deterioration in quality of the effluent, notably in the 5-day B.O.D., which rose from 20.2 to 35.2 p.p.m. The air supply was again started at the end of the thirty-third week and continued without interruption thereafter. During the latter part of the year, the dosage was equivalent to 205 gallons per cu. yd. per day dry weather flow.

No. 2 Filter.—After the fifth week the dosage was increased by gradual steps, the aim being to maintain 50 per cent purification based on the 4-hour oxygen absorption test. Increased dosage caused a temporary drop in effluent quality, followed by an improvement until the dose was further increased. The regularity of this behavior indicates that even at the maximum dosage obtained—1070 gal. per cu. yd. per day—the limit of filter capacity has not been reached. At this maximum rate, the purification has been nearly 60 per cent on the basis of the 4-hour oxygen absorption test, and about 75 per cent on the basis of the 5-day B.O.D. removal. At no time have there been signs of ponding.

Summary and Conclusions.—The proprietors of the enclosed filter process claim that a deep enclosed aeration filter used for complete treatment will treat three times as much sewage per cu. yd. as an ordinary open filter and will produce an effluent of equal qual-

ity. The authors conclude that this claim does not appear to be unreasonable. The shallow enclosed filter has shown great promise as a partial purification plant.

Records of temperature show that the conservation of heat brought about by enclosing a filter, thus reducing losses from sprays and the surface of the bed, more than counterbalances the cooling effect of the forced ventilation.

Freedom from flies and odors is an important claim for the enclosed filter. With No. 1 filter, although there have been many flies in the bed, very few have found their way into the effluent chamber and only a faint earthy odor has been perceptible. Fair numbers of flies have at times escaped into the effluent chambers of No. 2 filter (partial treatment), and a typical "sewage" smell has been noticeable at intervals, but the odor has never been very strong.

It is considered that results already obtained show that the process is capable of utilization on a practical scale.

R. S. SMITH

CITY OF MANCHESTER, RIVERS DEPARTMENT

Annual Report, Year Ending March 31, 1938

Pamphlet, 46 pages plus 7 pages of tables and 2 charts

This report contains the description and summary of operation of the sewage treatment works of the city, the principal plants being the Withington and the Davyhulme works.

Withington Works.—At the Withington Works, with an area of 92.5 acres, an average sewage flow of 1,838,200 gallons per day is treated. The contributing population is 47,000. The sewage is screened and passed through detritus, sedimentation and Emscher tanks. About 57 per cent of the effluent from the tank treatment was treated by the activated sludge process and 43 per cent was dealt with on filtration areas. The primary filter beds were operated at an average rate of 117,000 gallons per acre per day. The activated sludge process is carried out in one small and one large diffused air unit. The effluent from this plant consists of a mixture of the discharge from the secondary contact bed and the activated sludge plants. The average analytical results for this effluent for the year (expressed in p.p.m.) were as follows: four-hour oxygen absorption 14.8, ammoniacal nitrogen 19.2, nitrous nitrogen .15, nitric nitrogen 1.6, B.O.D. 28.5 and suspended solids 15.0.

Davyhulme Works.—The sewage from a contributing population of 813,000 reaches the Davyhulme works through two main outfall sewers, 10 ft. and 13 ft. in diameter. The sewage which flows over the storm-water sill passes through eight settling tanks with a total capacity of 11,000,000 gallons, and is then discharged into the ship canal. The sewage receiving full treatment passes first to six detritus tanks which have a total capacity of about 50 minutes dry weather flow. This sewage then passes into eight settling tanks. The effluent from four of these tanks is treated in the new activated sludge plant while the effluent from the remaining tanks is treated on 46 acres of primary and 39 acres of secondary contact beds. Two new primary tanks 56 ft. by 326 ft., with an average depth of 12 ft., are under construction. These tanks will be equipped with a Mieder sludge removing mechanism. The average sewage flow to the plant was 48,613,000 gallons, a decrease of 11.09 per cent from the previous year. The average analytical results of the raw sewage (expressed in p.p.m.) were as follows: four-hour oxygen absorption 127.6, ammoniacal nitrogen 29.9, suspended solids 237 and B.O.D. 236.5.

A total amount of densified sludge equal to 472,820 tons was removed from the plant. Of this 288,680 tons were disposed of at sea by the two sludge steamships "Manxunium" and "Salford City." The quantity of sludge disposed of on land areas was 184,140 tons. This sludge, in as fresh a condition as possible, is broadcasted on lightly ploughed land, with final incorporation into the soil by harrowing and ploughing. The sludge digestion plant was described in the previous report and a paper on the

performance of the plant was given elsewhere. (Summer Conference of the Institute of Sewage Purification held in Glasgow in July, 1938.)

The filtration area consists of 92 half-acre beds. These were dosed at an average rate of 429,000 gallons of tank effluent per acre per day. The purification effected by them averages between 48 and 50 per cent on the basis of the four-hour oxygen absorption, calculated on raw sewage. The secondary contact beds receive 21 fillings per week in the summer, with one week's rest in every four, and 18 fillings per week in winter. The purification effected on raw sewage, calculated on the four-hour oxygen absorption test, is 74 to 77 per cent and 85 to 87 per cent on the basis of B.O.D.

An average of 24,730,000 gallons of tank effluent was treated daily by the activated sludge units at Davyhulme, the flow being divided between a bio-aeration unit, a Simplex unit and two diffused air units. The operating results of these units are summarized below:

AVERAGE ANALYTICAL RESULTS (EXPRESSED IN P.P.M.), VOLUMES TREATED, ETC.

	4 Hours Oxygen Absorption (at 26.7° C.)	NO_3 N	NO_2 N	B.O.D.	Suspended Solids (Total)	Average Volume Treated per Day	Average Detention Period (Hours)	Average H.P. per Million Gallons	Percentage Reduction of B.O.D.*
Raw Sewage	127.6	—	—	236.5	237	—	—	—	—
Settled Sewage	94.9	—	—	172.8	93	—	—	—	—
Bio-aeration Plant	25.7	0.1	1.1	16.7	17	602,000	18.3	45.6	90.4
Simplex Plant	23.8	0.1	1.1	13.4	15	1,167,200	13.7	29.3	92.3
Diffused Air Unit 1	24.7	0.15	1.0	14.8	18	3,252,600	10.2	33.8	91.5
Diffused Air Unit 2	24.3	0.1	1.0	13.7	17	3,234,000	10.2	34.0	92.1
Combined Units	24.6	0.15	.9	15.1	18	16,473,400	10.1	33.4	91.3

* Calculated on basis of settled sewage.

Daily sewage flow ..... = 48,613,000 gallons

Sludge disposed of (after densification)

Settling tank sludge ..... = 274,750 tons
Activated sludge ..... = 178,850 tons
Digested sludge ..... = 19,220 tons

Total ..... = 472,820 tons
= 26.6 tons per million gallons

Total volume of sewage filtered

Primary contact beds ..... = 40.6% of the sewage flow
Volume of sewage treated by activated sludge ... = 50.9% of the sewage flow
Total volume filtered by secondary beds ..... = 78.2% of the primary effluent
= 31.7% of the total flow

Total cost (not including interest and repayment of debt) ..... = £3 11s 1.4d per million gallons

Average cost per capita:
For year ending March 31, 1938 ..... = 1s 6.6d

Research Work.—Experimental work had been directed toward densification of activated sludge. The method of settling sludge in contact with slowly rotating vertical screens, as described in the Annual Report for 1934, only rarely concentrated the solid matter to 2.0 per cent. Promising results were obtained by centrifuging, which produced a sludge containing up to 5.3 per cent of dry matter. It has been suggested that

a solid matter content of 3.5 per cent was the ideal which permitted considerable reduction in volume with a final product not too viscous to pump. Variations in character of activated sludge were studied. A case of sludge bulking occurred that was not due to change in pH, lack or excess of oxygen in solution, the presence of filamentous organisms or of excessive amounts of grease, but appeared to be due to the normal decrease in density experienced during dry weather together with a lowering of the critical weight of the sludge beyond which settling is retarded.

C. C. RUCHHOFT

SOME RECENT DEVELOPMENTS IN SETTLING TANKS

BY H. LORAIN FOLKES

The Surveyor, **94**, 475–478 (October 28, 1938)

The author devotes the first part of the paper to a discussion of the functions of settling tanks, with particular emphasis upon the utilization of tanks for equalizing variations in strength and quantity.

In order to provide equalization in rate of flow, settling tanks must be variable in capacity. This variation in capacity may be accomplished by the use of two outlet weirs or by some type of manual control of the water level. The disadvantages of these methods of capacity control are overcome by a tank built at Alte Emscher by the Ruhrverband in Germany, and the major part of the paper is essentially a description of this tank, with its effluent weirs for automatically varying the capacity in proportion to the flow, and its sludge removal mechanisms.

The tank is circular in form, 222 ft. 9 in. in diameter, and the average depth varies from 10 ft. at minimum to 13 ft. 3 in. at maximum flow. The inlet is situated in a central chamber with a vertical baffle. From this inlet chamber the flow passes through a grill of vertical pipes to insure even distribution. The variation in capacity is obtained by using seventy-one floating telescopic weirs, over which the effluent flows to a peripheral outlet channel.

The curved outlet pipes of the telescopic weirs are 7⅞ in. in diameter, with the horizontal discharge end fixed in the tank wall and the vertical part fitted with a flange to support the telescoped tubes. Four short tubes are fitted concentrically around the fixed vertical pipe, each having a shoulder on the inside at the bottom and on the outside at the top. The outer tube is fixed by brackets to an annular bronze float 3 ft. in diameter and 1 ft. 1½ in. deep. A steel rod runs down the center of the tubes and is connected to the float and upper tube by a bracket and sliding ring to insure that the float and tubes move in a vertical line. This rod is screwed at the bottom to the inside of the curved fixed pipe and is supported at the top by a bracket fixed to the tank wall above the maximum water level. Thus as the flow increases, the floats raise the weirs, increasing the capacity of the tank. At the same time, the weight of the telescopic tubes increase the submergence of the floats and the weirs, thus increasing the rate of outflow.

The sludge removal apparatus of this Alte Emscher tank is rather unusual. The tank is fitted with a bridge spanning half the tank and supported on rails on the 31-ft. diameter central inlet chamber and on a circular grill wall which divides the tank into an inner and outer zone at 80 ft. 7 in. from the center. Sludge settling in the inner zone is swept into a central sludge well by means of 33 scraper blades consisting of one row of triple blades near the center, three rows of double blades and six single blades near the division wall. The scrapers in the outer zone consist of four converging pairs of plows which push the sludge to the inlets of four air lifts discharging to the central hopper.

Mention is also made of two 130-ft. diameter radial flow tanks at Viersen, Germany, with parabolic one-piece scrapers suspended by rods from a revolving bridge. With this design, it is not necessary to operate the sludge removal apparatus for long periods at a time as all sludge is removed by one revolution of the bridge.

The bridges over these tanks are pivoted at the center and run on rails on the central chamber and the outlet wall. The drive is by means of a rail with vertical teeth fitted to the outside of the rail on the outer wall, vertical teeth being used to minimize difficulties from ice forming in the teeth. Two vertical 1½ H.P. geared motors are used to drive the bridge, and these are attached to horizontal pivoted arms fitted to each end of the bridge. The driving pinions are kept in mesh with the toothed rail by guide pinions. One revolution of the bridge, taking one hour, suffices to remove all sludge that has settled in the tank during the entire day.

R. S. SMITH

DISPOSAL OF MILK WASTES AND MILK BY-PRODUCTS

BY DEWI DAVIS

The Surveyor, **94**, 316 (1938)

Waste water from milk depots, containing approximately 1 per cent of whole milk, has a B.O.D. of about 1200 p.p.m., whereas the waste from cheese or butter factories is much stronger. The B.O.D. of buttermilk is seldom less than 65,000 p.p.m., and of whey is generally over 40,000 p.p.m.

The small amount of butter fat in the whey may be removed by centrifuging or the whey may be dried and incorporated in cattle and poultry food. The skim milk obtained in butter making may be dried and converted into acid casein.

Small volumes of dairy wastes may be treated in conjunction with domestic sewage but where large volumes are encountered they are detrimental to the biological processes, because of a high oxygen demand, fermentation to organic acids, filter clogging, and sludge bulking.

The treatment of dairy wastes by biological filtration and the activated sludge process was carried out at a depot which handled 35,000 to 40,000 gallons of milk per day.

In the biological filtration of dairy wastes, the following steps were used:

(*a*) Sedimentation of the crude waste.
(*b*) Dilution of the settled waste with purified effluent.
(*c*) Distribution over the first filter by means of a rotary distributor.
(*d*) Sedimentation.
(*e*) Distribution over the second filter.
(*f*) Final settling.

By using the filter beds in series, clogging was avoided. Approximately 99 per cent purification was obtained, the final effluent having a B.O.D. of about 7 p.p.m.

In the treatment of dairy wastes by the activated sludge process, the primary settled waste was diluted with final effluent and most of the sludge from the final settling tank was returned to the inlet end of the aeration tanks, any surplus sludge being deposited on sludge-drying beds. The B.O.D. of the final effluent was about 20 p.p.m.

In contrast to these two methods of treatment, another method has been used in which the wastes are allowed to ferment under controlled conditions of temperature and aeration, during which the fat and casein separate out. After sedimentation the supernatant is treated on percolating filters. This process gives approximately 99 per cent B.O.D. removal. The initial fermentation is necessary—otherwise the casein thrown out during filtration would block the filter media.

W. A. MOORE

EFFECTS OF INDUSTRIAL WASTES AND SEWAGE ON SHELLFISH AND FIN FISH

By L. M. Fisher

Civil Engineering, 8, 454–456 (July, 1938)

Pollution of streams and coastal waters by industrial wastes and sewage has a direct bearing on public health because shellfish have been involved in the spread of disease. Indirectly, public health is affected because pollution of coastal streams makes certain valuable sea foods scarce and more expensive. Among the causes of the increase in stream pollution may be mentioned: rehabilitation of the fermentation industries, the sudden growth of the cellulose-textile industry, development of mid-continental oil fields and gradual extension of mining. In the section north of the Ohio and Potomac Rivers and east of the Mississippi, containing 65 per cent of the total urban population, the problem is more acute.

Shellfish and fin fish may be affected by sewage and industrial wastes because of: decrease in oxygen, increase in acidity or alkalinity or salt content of the water, introduction of toxic substances, reduction in fish food due to increase in turbidity, and by sludge deposits which destroy fish food living on the stream bottom. The polluting material reaching streams in greatest volume and affecting the largest stream bed area is probably acid mine waste coming principally from coal mines. In recent years W. P. A. mine-sealing projects have tended to reduce this acid mine drainage.

Oil content of municipal sewage, and, in coastal waters, oil from bilge water of vessels retards the development of diatoms, chief food of oysters; and reduces the rate of feeding by a narcotizing effect on the oyster. Contamination of oysters by pathogenic organisms in the sewage has been held responsible for the spread of disease and led to the minimum requirements for the sanitation and certification of the shellfish industry by the U. S. Public Health Service. Large areas formerly used for production of shellfish have been abandoned because of excessive pollution.

Pulp and paper wastes cause trouble due to: (1) fiber deposits, which inhibit normal growth of plant and animal life; (2) excess alkali wastes, which are detrimental to aquatic life; (3) mercaptans, produced in the cooking process of sulfate pulping operations, which are toxic to fish life in concentrations as low as one part per million; (4) waste liquor from sulfite processes uniting with dissolved oxygen in the stream, and (5) acidifying nature of this sulfite waste.

The Bureau of Fisheries concluded after systematic studies on the York River that: "the presence of pulp mill wastes in the water is the cause of the failure of oysters to grow and fatten in the upper part of the river and that the elimination of pulp mill pollution is a prerequisite for the restoration of the oyster industry in the York River."

Studies have shown the pulp mill waste can be utilized to make—bakers' yeast, alcohol, and binder material for road purposes; it can also be used as a base for linoleum cements. Other products such as tanning extracts, phenol, vanillin and fertilizer material can be obtained by precipitation methods.

More research is pointed out as the answer to the problem in industrial waste control. Methods for utilizing wastes or economical methods for their disposal must be sought. Public funds should be provided to maintain research laboratories to evolve such methods, as a supplement to contributions by the industries. It is apparent that the time is rapidly approaching when an intelligent and comprehensive plan must be evolved for dealing with the problem of effective cleaning of streams and coastal waters. If industry and government cooperate it will be easier, less costly, and less disruptive than if an aroused public demands immediate and drastic action.

Frank E. DeMartini

THE DETROIT SEWAGE TREATMENT PLANT

By Clarence W. Hubbell

Civil Engineering, **8**, 667–669 (October, 1938)

The Detroit Sewage Treatment Plant includes intercepting sewers, a pumping station, racks, grit chambers, plain sedimentation tanks, sludge digestion and elutriation tanks, sludge filters, incinerators for raw and digested sludge, screenings and grit. Provision is also made for chlorination of effluent.

The intercepting sewers are designed and built to serve an ultimate population of 9,000,000 and have a maximum capacity of 2,000 cu. ft. per second. The average per capita flow is estimated at 175 gal. per day. A surge basin of 14,400 cu. ft. capacity is provided for protection of structures and equipment in the interceptors and plant, and to prevent street flooding through manholes.

A circular pumping station with outside diameter of 113 ft. will be equipped with eight motor-driven centrifugal pumps. The average lift is about 30 feet. The present plant installation will serve a population of 2,400,000 and an average flow of 420 m.g.d. as of 1950.

The rack screens, with net openings of ¾ in., are mechanically cleaned. There are eight grit chambers, each 160 ft. long by 16 ft. deep. The width varies with the capacity of pump served, to give an average velocity of 1 ft. per second. Screenings are to be ground and returned to the sewage. Grit is to be incinerated. An average removal of 21 cu. yd. of screenings and 62 cu. yd. of grit per day is expected.

The sedimentation tanks are 272 ft. 8 in. long, 16 ft. wide, and 14 ft. deep, and will provide an average detention period of 1½ hours. There are eight units of seven tanks each, and each is covered with low-slab, sod-covered roofs. The effluent from these tanks will be treated with an estimated average of 10 p.p.m. of chlorine, and then discharged into the Detroit River through an 18 ft. diameter tunnel which terminates in a submerged crib located about 400 ft. beyond the harbor line. The crib is about 40 ft. deep and in swift flowing water.

Under the present plan of operation the raw sludge from the sedimentation tanks will be conditioned with lime and ferric chloride, dewatered by vacuum filters and incinerated. The estimated average production of sludge in 1950 will be 240 tons of dry solids per day. The quantity of sludge cake to be incinerated is estimated at 922 tons per day, which includes about 36.5 tons of residual solids from conditioning chemicals. The moisture content of the cake is estimated at 70 per cent. The production of ash will be 125 tons per day. Twelve vacuum filters of the blow-back scraper type are provided, each with 500 sq. ft. of effective filtering area. Four incinerator units of the circular, multiple-hearth type, with a total capacity of 1200 tons per day, will be provided. This incinerator capacity is deemed adequate for a population of 2,400,000 on the basis of incinerating raw sludge, and for an ultimate population of 4,000,000 on the basis of incinerating digested sludge.

The original project called for eight digestion tanks, each 105 ft. in diameter and 42 ft. in depth, and also an elutriation plant prior to dewatering and incineration. Because of lack of funds, only one digestion tank and one-eighth of the elutriation plant are to be built at this time.

The revised estimated cost of the entire project as of September 1, 1938, is $22,635,000, of which $19,030,000 is for construction and the remainder for preliminary costs, land and engineering.

S. G. Monroe

SEWAGE DISPOSAL AT DENVER, COLORADO

By E. B. Black

Civil Engineering, 8, 578–580 (September, 1938)

The sewage treatment plant at Denver, which went into operation in January, 1938, is of interest to engineers in the arid sections because of its close relation to irrigation. Colorado holds legal title to the sewage of Denver. The entire flow of the South Platte River below Denver is appropriated for irrigation, 130,000 acres being thus served within 25 miles of the city. As 18,500 acres are devoted to intensive truck gardening, the use of sewage-laden water constitutes a health menace.

Denver sanitary sewage has averaged 21.5 per cent of the total flow of the South Platte, excluding floods, and on individual days, more than 97 per cent of the flow, with resulting serious nuisances along the river and in the irrigation canals, due in part to sludge deposits. The State Board of Health has fixed the maximum allowable 5-day B.O.D. in the river below Denver at 40 p.p.m., requiring a minimum flow of 4500 sec.-ft. This flow has occurred on only 28 days in a 46-year period of record; hence it has been necessary to provide sewage treatment. The new plant has been designed for preliminary treatment to prevent sludge deposits, and when supplemented by dilution or chemical treatment, to produce an effluent coming within the allowable pollution. In addition to the flow of the river, 12,000 acre-feet of dilution water will be required annually as long as the sewage is given only primary treatment. This will be provided by diversion of water through a tunnel from the Williams Fork of the Grand River, on the western slope of the continental divide.

Denver is sewered on the separate plan, serving 270,000 persons (85 per cent of the total population) and estimated at 370,000 by 1948. The treatment plant is located on a 38-acre site just inside the north city limits. Design is based on an average flow of 54 m.g.d. or 170 gal. per capita from a contributing population of 317,000. Equipment has been provided for screening, grit removal, chemical coagulation, pre-aeration and mixing, sedimentation, mechanical filtration, sludge digestion and sludge disposal by air-drying.

After flowing through venturi meters, the raw sewage passes through three 5 ft. by 6 ft. channels equipped with mechanically-cleaned screens; thence through an overflow chamber with weirs set to by-pass flows exceeding 90 m.g.d. into two grit removal tanks equipped with mechanical cleaners; thence into an aeration tank 140 ft. long with two compartments, each 20 ft. wide and 16 ft. deep, providing 15 minutes retention and equipped for addition of coagulant; thence through two compartments of the mixing basin, each 140 ft. long, 16 ft. wide and 16 ft. deep, equipped with paddle agitators; thence through a flume to a well which serves four settling basins with central feeds, peripheral overflows, and clarifiers, providing 2 hours retention.

After settling, sewage flow exceeding 80 m.g.d. will be by-passed to the river and the remainder filtered through six magnetite filters with a total filter area of 14,000 sq. ft. The sand has an effective size of 0.5 mm. and the beds are 3 in. thick. The normal filtration rate is 2.68 gal./sq. ft./min., with a maximum of 4 gal./sq. ft./min. Each filter is equipped with a solenoid-operated cleaner which travels the length of the bed, 172 ft., and washes a strip of sand 13 ft. long and 1 ft. wide without interfering with the operation of the filter. Filtered sewage is used for washing and wash water is returned to the aeration tank for retreatment.

Sludge from the settling basins is pumped to four digesters which have a total capacity of 681,000 cu. ft., equivalent to 2 cu. ft. per capita, including industrial load. Three of the digesters are equipped with floating covers and the skirt of the fourth is extended downward to provide storage of 30,000 cu. ft. of gas. Temperature is controlled by circulation of hot water from boilers fired with sludge gas. Under normal conditions three of the tanks will receive raw sludge and the fourth will be used for storing digested sludge and supernatant liquor. Digested sludge is air-dried on 12.5 acres of undrained sand beds. Dried sludge is shoveled by hand to motor-driven belt conveyors.

Owing to the distances from chemical factories and the consequently high cost of

ferric chemicals, provision is made for manufacturing chlorinated copperas and ferric chloride at the sewage plant from basic materials. As ferric chloride cannot be stored, provision is made for dry-feeding copperas into the oxidizing tube and for feeding additional chlorine to make up required amounts of ferric iron.

Operation was begun early in May, 1938. Without chemicals, the plant reduced the B.O.D. from 140 to 63 p.p.m. in May and from 137 to 51 p.p.m. in June. The Platte River below the plant showed an average of 6 p.p.m. B.O.D. in May and 22 p.p.m in June. Suspended solids were reduced from 150 to 28 p.p.m. in May and from 178 to 27 p.p.m. in June.

The cost of the project is stated as follows:

Sewage treatment plant	$1,477,769
Main sewer extensions, etc.	153,213 *
Williams Fork Diversion Project	1,778,800
Total	$3,409,782

H. W. STREETER

ANNUAL REPORT OF THE COMMISSION FOR POLLUTION AND GOVERNMENT INSTITUTE OF SEWAGE AND WASTE PURIFICATION, YEARS 1936 AND 1937

BY H. KESSENER, *Director, The Hague, Holland*

The conception that laws, rules and regulations of stream pollution, sewage and waste treatment must be supplemented by technical help and advice has continued to form the basis of work of the commission and institute. This requires a vast amount of detailed investigation of actual conditions, formulations of plans and procedures for abating pollution and direct advice to municipalities and industries. In order to advise the polluting agencies the institute tests the feasibility of new methods of treatment, improves existing and develops new devices. Working in close co-operation with government agencies dealing with public works, unemployment relief and government construction, possible sources of pollution could be prevented or stream pollution reduced.

The report is divided into five sections: (1) water pollution, (2) advice to government, provincial and municipal agencies, (3) advice to public works, unemployment relief, etc., (4) construction and operation of treatment plants, and (5) advice and help to institutions and industries. Pollution of many of the smaller streams is most prevalent in industrial areas. The investigations take into consideration the cause and degree of pollution leading to necessary action. A great variety of industrial wastes, including textile, slaughterhouse, dairy, potato starch, paper, laundry, fat rendering, oil refining, steel, petroleum, flax, hair, pharmaceutical and chemical, mine, etc., have been studied and reported upon. Pollution by garbage and refuse disposal are now subjected to more regulation. Definite methods of garbage dumping are prescribed. Problems relating to many municipal sewage treatment methods and devices are discussed. The co-operation with public works and unemployment relief and the advice given not only saved considerable money, but prevented installations of improper structures and aided materially in alleviation of many old sources of pollution.

Some of the new sewage treatment plants built require special mention. The new activated sludge plant at Hilversum has been built on the basis of extensive experiments. The plant consists essentially of screens, detritors, pre-settling, digesters, brush aeration tanks and drying beds. The seeding, mixing and heating of the sludge is performed in a small cylindrical tank, with a horizontal, revolving shaft, with secondary, and, if necessary, tertiary digestion in larger tanks (Fig. 1). Another interesting plant placed in operation is at Vught. The plant, consisting of sedimentation, digestion, brush aeration and secondary settling, has some new features. The digesters are equipped

* City's share; W.P.A. costs not included.

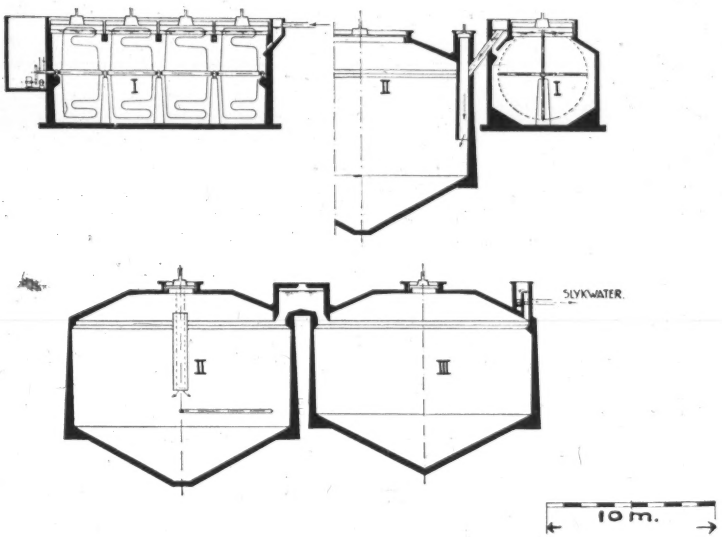


FIG. 1.—Cross-section of digestion tanks at Hilversum.

with horizontal mixing devices, while the aeration tanks have automatic sludge return, which varies with the sewage flow. The plant at Tilburg, which receives large quantities of textile, dye and other industrial wastes, is essentially a chemical treatment plant, but alongside has been built an experimental plant. Not only can direct comparisons be made with the activated sludge unit, but the effluent of the chemical treatment plant can be used, or pre-aeration without activated sludge can be practiced. The experimental unit is equipped with various meters, regulators and automatic samplers. A number of other plants are mentioned, some of which have been projected, are under construction or have been built. Average results for the years 1936–37 of some of the treatment plants are of interest:

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	Inf.	Eff.	Inf.*	Eff.	Inf.*	Eff.	Inf.	Eff.	Inf.*	Eff.
5 day B.O.D.	227	16	200	9	1260	3	358	29	276	13
Ammonia-N	29.1	6.4	38.4	6.4	315.9	0.2	49.3	15.0	66.5	37.1
Nitrate-N	—	64.8	—	45.2	—	40.0	—	46.8	—	50.0
Ox. Cons., 10 min	117	31	96	20	452	16	168	48	133	19
pH	7.9	7.9	8.2	7.8	8.2	7.8	7.5	7.8	7.4	8.1

* Effluent from sedimentation units.

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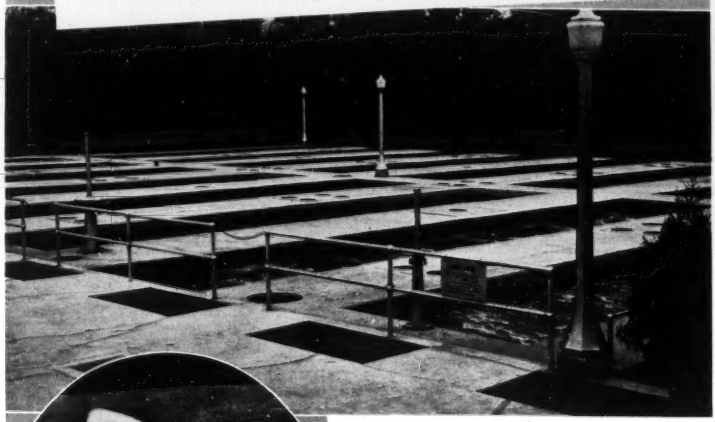

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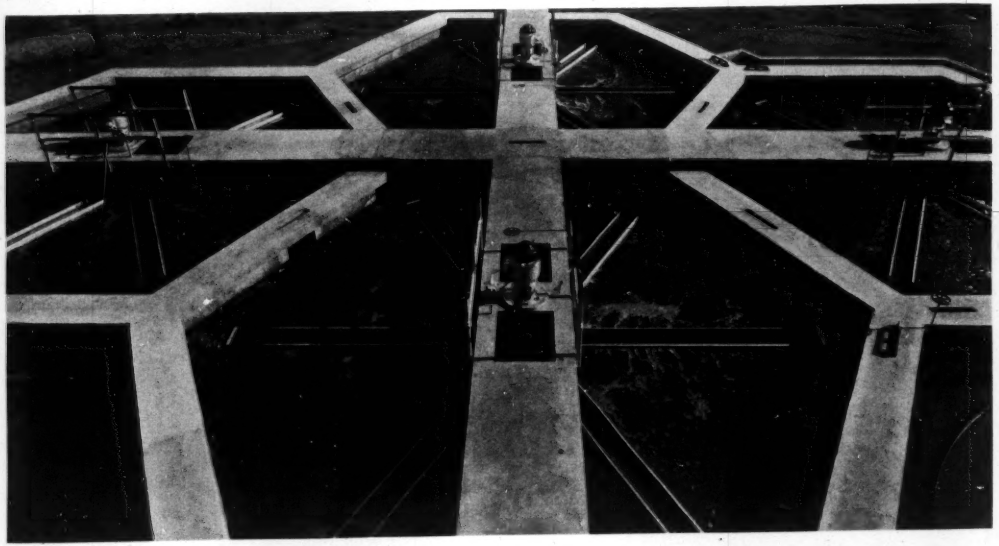

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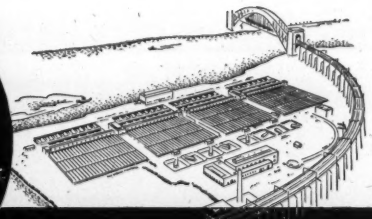

RIGHT—*Air-filter of secondary room. Framework of filter structure, holders and mesh are welded and bolted Everdur Sheet and Strip. Fabricated by American Filter Co., Inc.*

ABOVE — *Control mechanism of 12" diameter Everdur float tubes. Designed by Krajewski-Pesant Mfg. Corp.*

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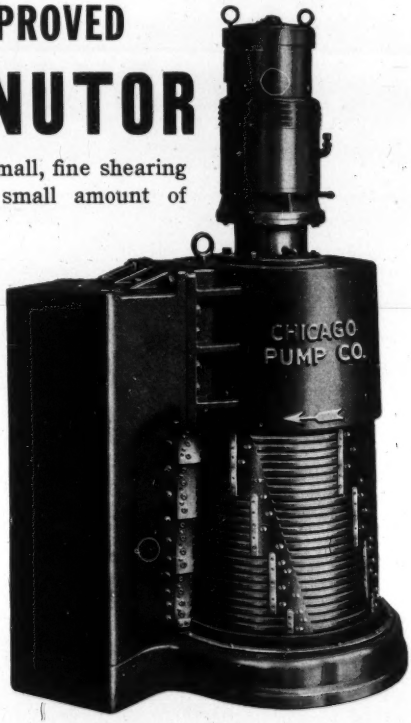

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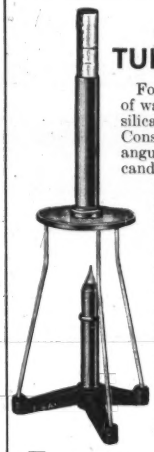

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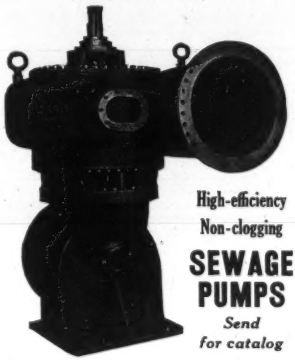

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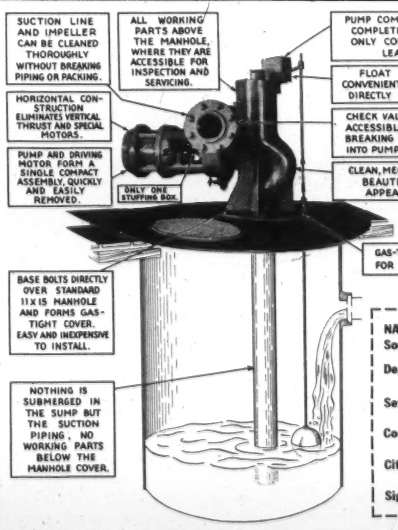
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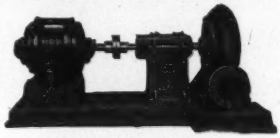

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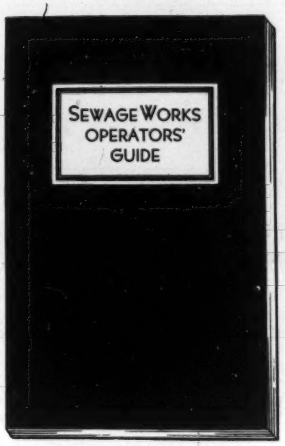

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